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The Relevance and Potential Impact of Kyoto Protocol Mechanisms for the Canadian Agriculture and Agri-food Sector

Economic and Policy Analysis Directorate
Policy Branch

March 2000

Canada

THE RELEVANCE AND POTENTIAL IMPACT OF KYOTO PROTOCOL MECHANISMS FOR THE CANADIAN AGRICULTURE AND AGRI-FOOD SECTOR

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Foreword

This study was commissioned by Agriculture and Agri-Food Canada to assess, qualitatively, the relevance and potential impact of an international tradeable permit system, the Clean Development Mechanism and Joint Implementation in the likely event that the Canadian agriculture and agri-food sector has to reduce greenhouse gas emissions. This study resulted in two reports: *"The Relevance and Potential Impact of Kyoto Protocol Mechanisms for the Canadian Agriculture and Agri-Food Sector" and "Possible Domestic Policies to Manage Greenhouse Gas Emissions."*

The Kyoto Protocol, if ratified by the Canadian Government, would require Canada to reduce its greenhouse gas emissions by 2008–2012, affecting almost every industry and consumer. With emission levels in agriculture increasing since 1990, the sector may be required to reduce its emissions as part the national strategy that is being developed. The sector would be affected by abatement costs to reduce its own emissions and by higher input and transportation costs as other sectors deal with their emissions. Regardless of future policy actions, the agriculture and agri-food sector will be affected by climate change since it is dependent on the weather which is expected to change as the concentration of greenhouse gas increases in the atmosphere.

The Kyoto Protocol has mechanisms to assist countries in achieving emission reductions. One mechanism allows for the development of international trading in greenhouse gas emissions permits among Annex I (mainly industrialized) countries. Investment in emission reduction projects in other countries in return for a share of tradeable emission credits through the Clean Development Mechanism or Joint Implementation would also be permitted. These three Kyoto Protocol Mechanisms are meant to assist countries in achieving compliance with their quantified emission reduction commitments at the least cost while achieving sustainable development and contributing to the ultimate objective of the UN Framework Convention on Climate Change. Theoretically, an emission trading system would result in the adoption of least-cost abatement practices among industries and countries. Developing least-cost policy instruments to reduce greenhouse gas emissions is important as the efficiency of the policy instruments would affect the environmental standards that society is willing to accept. To date we only have limited experience with economic instruments such as tradeable permits to reduce emissions or other sources of pollution.

The debate on the use of economic instruments to reduce greenhouse gas emissions has been going on for well over a decade, largely out of public sight in highly technical international forums or within the fossil fuel and the energy sector. With the signing of the Kyoto Protocol, this debate must now involve the public. These two reports are intended to familiarize stakeholders in the agriculture and agri-food sector, as well as other interested parties, with the concepts, issues and terms surrounding the use of economic instruments (such as tradeable permits) to reduce greenhouse emissions in Canada and around the world.

John C. Giraldez
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Executive Summary

The purpose of this report is to assess the relevance and potential impact of the Kyoto Protocol mechanisms on Canada's agriculture and agri-food sector.

The Kyoto Protocol establishes greenhouse gas emission limitation or reduction commitments for 38 wealthier countries, including Canada. It includes three mechanisms that enable a country to help meet its commitment through actions implemented in other countries:

- International emission trading (IET) between Annex I parties (Article 17) involves transfers of *assigned amount* between Annex I countries.
- Joint implementation (JI) between Annex I parties (Article 6), involves transfers of *emission reduction units* created by emission reduction or sequestration actions in one Annex I country with financial assistance from another Annex I country.
- Clean development mechanism (CDM) (Article 12), involves transfers to Annex I parties of *certified emission reduction credits* created through emission mitigation projects implemented in developing countries with financial and other assistance from Annex I countries.

When distinctions among assigned amount, emission reduction units, and certified emission reduction credits do not matter, they are referred to as Kyoto Protocol instruments. Most studies suggest that Canada is likely to be a net importer of Kyoto Protocol instruments. The reason is that the costs of emission reduction and sequestration measures are estimated to be lower in Eastern European and developing countries than in Canada.

Greenhouse gas emissions by the agriculture and agri-food sector amount to at least 78,000 kt carbon dioxide (CO_2) equivalent, which was over 10 percent of Canada's total emissions during 1995. Soils are the largest component of these emissions. Nitrous oxide (N_2O) emissions from soils and synthetic fertilizer use together with the CO_2 emissions from soils represent about 45 percent of the sector's emissions. Methane (CH_4) emissions due to enteric fermentation together with the CH_4 and N_2O emissions from livestock manure, account for almost 35 percent of the sector's emissions. Fossil-fuel CO_2 emissions represent less than 25 percent of total greenhouse gas emissions by the agriculture and agri-food sector.

Estimates of the potential for sequestration in agricultural soils, if it is allowed under the Kyoto Protocol, range from 8,000 to 25,000 kt CO_2 equivalent per year until a new equilibrium is achieved. These figures are equivalent to 1.3–4.0 percent of Canada's current greenhouse gas emissions. If soil sequestration is allowed, sequestration in Canada could contribute between six percent and 18 percent of the reduction needed by Canada to achieve compliance with its emission limitation commitment.

The ability of a source to utilize the Kyoto Protocol mechanisms depends upon the applicable domestic policies. The potential to use the Kyoto Protocol mechanisms is greatest for sources of greenhouse gas emissions participating in a domestic emission trading program.

Few, if any, sources of greenhouse gas emissions in the agriculture and agri-food sector are well suited to participate in a domestic emission trading program. More comprehensive coverage of these emissions can be obtained with fewer participants by implementing the trading program "upstream" from the agriculture and agri-food sector:

- Energy-related CO_2 emissions could be addressed through a trading system for the carbon content of fossil fuels applied to fossil fuel producers and importers or by a trading program regulating CO_2 emissions by large energy users. The latter design would include a few large food processors while the former would involve no participants from the agriculture and agri-food sector.

- N_2O emissions associated with fertilizer use could be addressed through a trading program involving fertilizer manufacturers and importers.

- HFC emissions are likely to be addressed through a trading program for importers of HFCs. A trading program for HCFCs, which replace HFCs, is already established.

- Food processing plants with wastewater treatment, landfill or composting activities could be required to participate in the domestic emission trading program.

- Enteric fermentation and livestock manure emissions could be addressed by requiring processing plants to hold allowances for the emissions associated with the products they purchase. This approach is problematic however, because it does not reward individual farmers for actions that reduce such emissions.

Assuming that a domestic emission trading program for greenhouse gases incorporating fossil-fuel CO_2, fertilizer N_2O and HFC emissions is implemented upstream from the agriculture and agri-food sector, sources in the sector would face price increases for energy, fertilizer and HFCs. These price increases would provide an incentive to implement measures to reduce the corresponding greenhouse gas emission.

It is very unlikely that individual farmers would be required to be part of a domestic emission trading program because they are too numerous and the emissions of individual farms are too small. Individual farmers might be allowed to create credits for actions to reduce emissions from enteric fermentation and livestock manure, afforestation and reforestation, and possibly soil sequestration. Food processing plants might be able to create credits by reducing emissions from treatment of their wastes. These credits would likely be sold on the domestic emission trading market because, as a net importer, prices are likely to be at least as high in Canada as on the international market.

With the participation of the agriculture and agri-food sector in a domestic emission trading program for greenhouse gases limited to the sale of credits created through such actions, use of the Kyoto Protocol mechanisms by sources in the agriculture and agri-food sector to buy or sell instruments would be minimal. They would have no need to buy Kyoto Protocol instruments since they are not required to be part of a domestic trading program and they could sell the credits created on the domestic market for prices at least as high as those on the international market.

However, access to the Kyoto Protocol mechanisms by participants in a domestic emission trading program is important to the agriculture and agri-food sector because such access reduces the cost of compliance and hence the price increases faced by farmers and food processors.

Quantitative analysis of the issues would enhance understanding of the impacts of policies to limit greenhouse gas emissions and the impact of the Kyoto Protocol mechanisms on the agriculture and agri-food sector. There are six such issues:

- Impacts on fertilizer prices, fertilizer use and agricultural output assuming N_2O emissions due to fertilizer use were covered by a trading program for the nitrogen content of fertilizer, adjusted by an emissions factor, sold in Canada.
- Impacts on energy prices, farm energy use, and production costs for different agricultural products assuming the energy-related CO_2 emissions were covered by a trading program for the carbon content of fossil fuels sold in Canada.
- Costs of alternative measures to limit enteric fermentation and livestock manure emissions.
- Supply curves for carbon sequestration through afforestation, reforestation, and soil sequestration during 2008–2012 due to direct human-induced activity.
- Impacts on energy prices, energy consumption, waste treatment and disposal costs, and production costs for food and beverage industries assuming the energy-related CO_2 emissions were covered by a trading program for the carbon content of fossil fuels sold in Canada.
- Impacts on the competitiveness of the Canadian agriculture and agri-food sector, including trade in food products, due to compliance with the Kyoto Protocol.

Quantitative analysis of an issue requires a suitable model or framework. While many models of the agriculture and agri-food sector, the Canadian economy, and the global economy are available, it is possible, indeed likely, that none is ideally suited to the analysis of a particular issue. Nevertheless, it is usually possible to gain insights into an issue through the use of a combination of models. Quantitative analysis of many of the issues is possible using five available models:

- Canadian Regional Agriculture Model (CRAM) for analysis of impacts on agricultural output
- CENTURY model for soil sequestration

- macroeconomic models of the Canadian economy, such as IFSD, National Energy Board, Conference Board of Canada, Informetrica, DRI, and WEFA, to estimate the impacts on energy prices
- a model of international agricultural trade, such as the Basic Linked System (BLS)
- global models with a Canadian module, such as G-Cubed, AIM, MegABARE, Charles River Associates, and SGM, to assess the impacts on competitiveness, and of these, G-Cubed is the only model that explicitly incorporates international capital flows.

Most of the macroeconomic and global models do not include much detail on the agriculture and agri-food sector. Therefore, studies of the impacts of price changes, competitiveness, and food trade will probably require linked or coordinated analyses involving such models and models of the agriculture and agri-food sector.

Section 1: Kyoto Protocol Mechanisms

The purpose of this report is to assess the relevance and potential impact of the Kyoto Protocol mechanisms on Canada's agriculture and agri-food sector.

1.1 Emissions Limitation Commitments

The Kyoto Protocol establishes emissions limitation or reduction commitments for 38 wealthier countries, including Canada.[1] The emissions limitation or reduction commitments apply to each country's aggregate emissions of six greenhouse gases during the period 2008–2012, calculated as an average over these five years.

The six greenhouse gases covered by the commitments are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).[2] The commitments cover emissions of these six gases due to energy production and transportation, fuel combustion, industrial processes, solvents and other product uses, agriculture, and waste disposal.

Commitments are established relative to the baseline emissions level. A party's baseline emissions level for CO_2, CH_4, and N_2O is its 1990 emissions of those gases.[3] For HFCs, PFCs, and SF_6 a party may choose either its 1990 or its 1995 emissions level as the baseline.

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1. Each member country of the European Community has a national commitment. In addition, the European Community as a whole has a commitment equal to the aggregate commitment of its member countries. Thus, there are 38 countries and 39 parties to the Kyoto Protocol with emission limitation commitments. These parties are listed in Annex B to the Kyoto Protocol and are often called Annex B Parties. But the text of the Kyoto Protocol refers to Annex I Parties, as listed in Annex I of the Framework Convention on Climate Change. Annex I has been amended to be identical to Annex B with one exception. Annex I includes Turkey, which has asked to be removed from Annex I and has not ratified the Convention pending a decision on this issue. This report uses the term Annex I and refers to parties and countries.
2. The gases differ significantly in terms of their impacts on the climate system. Emissions of the different gases are converted to CO_2 equivalent tonnes using internationally agreed global warming potential (GWP) values. These values range from 1 for CO_2 to 23,900 for SF_6 over a 100-year time-horizon.
3. The former centrally-planned economies may, with the approval of the Conference of the Parties, choose a base year earlier than 1990.

A party's commitment is expressed as a percentage of its baseline emissions level. Canada's commitment is to limit its average annual emissions during the period 2008–2012 to 94 percent of its baseline emissions level,[4] a reduction of six percent from the baseline and of 20–30 percent from the projected emissions in 2010.[5]

1.2 The Kyoto Protocol Mechanisms

A party's aggregate emissions allowed for the 2008–2012 commitment period is its initial "assigned amount." The Kyoto Protocol includes three mechanisms that enable a party to increase its initial assigned amount:

- International emission trading (IET) between Annex I parties (Article 17) involves transfers of *assigned amount* between Annex I countries.
- Joint implementation (JI) between Annex I parties (Article 6) involves transfers of *emission reduction units* created by emission reduction or sequestration actions in one Annex I country with financial assistance from another Annex I country.
- Clean development mechanism (CDM) (Article 12) involves transfers to Annex I parties of *certified emission reduction credits* created through emission mitigation projects implemented in developing countries with financial and other assistance from Annex I countries.

An Annex I party's actual emissions for the commitment period (2008–2012) must be less than its adjusted "assigned amount" for the period.[6] Its adjusted assigned amount is a calculation:

adjusted assigned amount
= initial assigned amount as defined by Kyoto Protocol commitment
\+ assigned amount received from other Annex I parties
\- assigned amount transferred to other Annex I parties
\+ emission reduction units received from other Annex I parties
\- emission reduction units transferred to other Annex I parties
\+ certified emission reduction credits acquired from non-Annex I parties.

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4. Most parties have an emission reduction commitment of eight percent. The United States has a reduction commitment of seven percent. Hungary, Japan and Poland, like Canada, have a reduction commitment of six percent. Croatia has a reduction commitment of five percent. New Zealand, the Russian Federation and the Ukraine have an emission limitation commitment equal to their baseline. Norway's emissions are allowed to rise by one percent, Australia's by eight percent and Iceland's by ten percent from their respective baselines.

5. Canada chose 1995 as its baseline for HFCs, PFCs, and SF_6 because its emissions of these gases were higher in 1995 than in 1990. However, since the other three gases (CO_2, CH_4, and N_2O) dominate Canada's aggregate emissions, the term "1990 emissions" will be used to describe the baseline.

6. Parties must report their actual anthropogenic emissions of greenhouse gases by source and removals of greenhouse gases by sinks using approved estimation methodologies. These reports must be submitted annually and are subject to review by independent experts.

1.2.1 International Emissions Trading

International emissions trading (IET) is simply the transfer of parts of "assigned amount" between Annex I parties. Article 17 provides that the Conference of the Parties will "define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading." Beyond that, Article 17 states only that Annex I parties may participate in emissions trading "for the purposes of fulfilling their commitments" and that emissions trading "shall be supplemental to domestic actions" for the purpose of meeting those commitments.

Traded assigned amount ultimately must be transferred from one Annex I government to another. This transfer could happen directly or as a result of trades involving firms in the two countries. One Annex I government could transfer some of its assigned amount to the government of another Annex I country directly in return for financial or other considerations. But direct transfers between governments are expected to be less common than trades involving firms.

Current proposals allow firms to engage in IET.[7] A transfer of the assigned amount from the government of country X to the government of country M via firms in these countries might work as follows.[8] A firm that is part of a domestic emission trading program in country X exchanges surplus domestic allowances for equivalent units of the country's assigned amount.[9] These units of assigned amount are sold to a firm that is a participant in a domestic trading program in country M. The buyer transfers title to the assigned amount to its national government as part of the compliance process.[10]

Most studies suggest that if Canada were to engage in IET, it would be an importer of assigned amount from Russia and eastern European countries.[11] This situation exists because the costs of reducing greenhouse gas emissions are estimated to be lower in these countries than in Canada. The extent of Canada's imports of the assigned amount will depend on the market price relative to the price of certified emission reduction credits from the CDM, the

7. Proposals on how to implement international emission trading were tabled by two groups of countries at the sessions of the Subsidiary Body for Scientific and Technological Advice (SBSTA) and Subsidiary Body for Implementation (SBI) in June 1998. One proposal was submitted by the United Kingdom on behalf of the European Community and several other European countries. The other proposal was submitted by Canada on behalf of most of the remaining Annex I countries. The proposals are available from the UNFCCC web site at: FCCC/SB/1998/MISC.1/Add.3/Rev.1 and FCCC/SB/1998/MISC.1/Add.1/Rev.1 respectively. Additional submissions were tabled in advance of the fourth Conference of the Parties in Buenos Aires. These proposals are compiled in the web site at: FCCC/CP/1998/MISC.7

8. Brokers, who may facilitate trades, are ignored for the purposes of this discussion.

9. The government of country X could, but need not, use part of its assigned amount as the allowances for the domestic emissions trading system. If assigned amount is used in the domestic emissions trading program, a firm could sell surplus assigned amount to a buyer in country X or any other Annex I country. This description assumes that the domestic allowances differ from, but can be exchanged for, assigned amount because that is a more general case.

10. It is not essential that both countries have domestic emission trading programs for transfers involving firms to occur. The key requirements are that an entity acquire title to units of assigned amount from the government of the exporting country and that title be transferred to the national government of the importing country.

11. See for example, Standard and Poor's DRI, 1997, Table 12-2, p. B-62.

price of JI emission reduction units, and the costs of domestic reductions. Restrictions on the use of emissions trading to meet national emissions limitation commitments could also affect the quantity imported by Canada.

The main areas of disagreement that remain in the proposed rules for emissions trading concern limits on the use of acquired assigned amount to achieve compliance with national commitments (supplementarity) and mechanisms to ensure that only assigned amount surplus to compliance needs is transferred to other countries (liability).[12] Some countries want quantitative restrictions on the extent to which an Annex I party can rely on purchased assigned amount to achieve compliance while other countries prefer a qualitative interpretation of supplementarity.

Regardless of whether assigned amount is transferred directly between governments or indirectly through firms that engage in international emissions trading, it is the Annex I governments that are responsible for achieving compliance with their emissions limitation commitments. Annex I countries are sovereign nations. Penalties imposed on countries for violation of international agreements tend to be weak and difficult to enforce, so a trading system should rely more on incentives to comply than penalties for non-compliance.[13] The liability provisions need to create incentives to sell only surplus assigned amount.

1.2.2 Joint Implementation

Joint implementation (JI) has received less international attention to date than either IET or the CDM. It is clear from Article 6 that to qualify as a JI project, emission reduction actions must meet four requirements:

- be approved by the countries involved
- be located in a country that is in compliance with its emissions inventory and reporting obligations
- lead to emission reductions "additional" to any that would otherwise occur
- be supplemental to domestic actions for the purposes of meeting national emissions limitation or reduction commitments.

A JI project is expected to be implemented in one Annex I country with financial, technical or other assistance provided by another Annex I country. The emissions reduction (or sink enhancement) benefits would be shared by the participants. A project to reduce greenhouse gas emissions or enhance a sink helps the host country comply with its emissions limitation commitment since its actual emissions for the period 2008-2012 are reduced.

12. Article 17 states that "trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments . . . ."

13. Under these circumstances, seller "liability" may not provide sufficient assurance that the assigned amount transferred to other countries will be surplus to compliance needs.

Other participants can receive some of the "emission reduction units" created by the project. The assigned amount of the host country is reduced by the quantity of emission reduction units transferred to other countries.[14] The assigned amount of each country that receives emission reduction units is increased accordingly. Thus, the accounting process is essentially the same as for IET.

The internationally agreed rules for JI could define the process that every country should use to determine the number of emission reduction units to be awarded to an emission reduction project. Alternatively, determination of the emission reduction units to be awarded for a particular project could be left to the host government. This action respects national sovereignty and recognizes the incentive the host government has to ensure that emissions are actually reduced or sequestered.

Regardless of whether the determination is made using an internationally specified process or a process developed by the host country, a major issue will be the specification of the baseline from which reductions are measured. The baseline should be an estimate of the emissions in the absence of the JI project. JI projects then, will involve negotiations with the host government over the baseline and how the baseline might change over time. This can have a major impact on the number of emission reduction units earned by a project.

There are two major outstanding issues relating to JI:

- how to establish baselines, which also affect whether the emission reductions are "additional" to any that would otherwise occur
- how to implement the requirement that use of JI emission reduction units be supplemental to domestic action.

As in the case of IET, some countries want quantitative restrictions on the extent to which an Annex I party can rely on JI emission reduction units acquired from other countries to achieve compliance while other countries prefer a qualitative interpretation of supplementarity.

1.2.3 Clean Development Mechanism

The clean development mechanism has three purposes:

- to assist non-Annex I parties to achieve sustainable development
- to enable non-Annex I parties to contribute to the ultimate objective of the Convention (stabilizing atmospheric concentrations of greenhouse gases)
- to assist Annex I parties to achieve compliance with their emission limitation commitments.

14. The host government, then, has an incentive to ensure that the JI project actually reduces emissions before transferring emission reduction units.

CDM projects must meet three requirements:[15]

- be approved by each party involved
- provide real, measurable and long-term benefits related to mitigation of climate change[16]
- yield emission reductions additional to any that would otherwise occur.

CDM projects are expected to be financed by governments of, and firms from, Annex I countries. They could invest in specific projects or contribute to funds, such as the World Bank's Carbon Investment Fund or the Edison Electric Institute's UtiliTree fund, that invest in a number of projects. The CDM also has a responsibility to assist in arranging funding for suitable projects.

Investors are expected to receive most of the certified emission reduction credits generated by a CDM project.[17] A share of the proceeds, which will probably be interpreted as a share of the certified emission reduction credits, from each CDM project will be used to cover administrative expenses. A share of the proceeds will also be used to assist developing countries, which are particularly vulnerable to the adverse effects of climate change, meet the costs of adaptation.

The Conference of the Parties (COP/MOP) will designate entities with the authority to certify the emission reductions achieved by CDM projects. Certified emission reductions generated by CDM projects between 2000 and 2008 can be used by Annex I parties for compliance purposes during the first commitment period.[18]

The first meeting of the COP/MOP will elaborate modalities and procedures for the CDM with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities. A number of issues relating to the structure and operation of the CDM remain to be resolved. Supplementarity is one of these issues. Annex I parties are permitted to use certified emission reduction credits to contribute to compliance with "part" of their commitment. The wording differs from that for IET and JI, but the intent of limiting the use of the mechanism to ensure domestic action is the same.

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15. It is not clear whether projects to enhance sinks in developing countries will be eligible to create credits under the CDM.

16. The Kyoto Protocol states that projects must provide benefits related to mitigation of climate change. In practice this wording is likely to be interpreted as mitigation of greenhouse gas emissions.

17. CDM projects are located in non-Annex I countries. Since these countries do not have emission limitation commitments, they can not use the CDM credits. Most of the investors are likely to be from Annex I countries, which can use CDM credits to help meet their emission limitation commitments. So the investors are likely to receive most or all of the CDM credits while the developing country participants are likely to seek higher financial returns, technology transfer, training, and other benefits. Some non-Annex I governments may wish to retain a share of the CDM credits and bank them for use in meeting future emissions limitation commitments of their own.

18. The Kyoto Protocol indicates that it is possible to begin creating credits under the CDM in 2000. The rules must be formally adopted by the COP/MOP, which cannot meet until after the Kyoto Protocol comes into force. The first meeting of the COP/MOP is likely to be held after 2000. In November 1998, parties agreed to a work plan to develop the necessary rules and guidelines in time for COP 6 in late 2000. COP 6 could recommend adoption of the proposed rules with formal adoption by the COP/MOP after the Kyoto Protocol comes into force. The rules could include provisions to recognize any reductions achieved after January 1, 2000 which meet the applicable criteria.

1.2.4 Key issues to be resolved

The rules for the three Kyoto Protocol mechanisms remain to be developed. Considerable work has been done on the structure for IET. The main areas of disagreement relate to operational interpretation of the supplementarity provision and liability provisions to provide an incentive to sell only assigned amount surplus to compliance needs.

Article 17 states that "trading shall be supplemental to domestic actions" for the purpose of meeting a country's emission limitation commitment. Many European countries want to establish a quantitative definition of supplementarity to ensure that most emission reductions occur domestically. Canada and a number of other countries oppose such a definition.

The balance of host government responsibility and international supervision of JI projects remains to be agreed. The use of emission reduction units from JI projects is also subject to a supplementarity restriction which remains to be defined. Since JI emission reduction units transferred by a country lead to a reduction of its assigned amount, compatibility of these transfers with the liability provisions adopted for IET needs to be addressed.

The operational structure for the CDM remains to be agreed. The eligibility of sink enhancement and other types of controversial projects needs to be agreed.[19] As with IET and JI, the supplementarity provision for the CDM remains to be defined in operational terms. Supplementarity could be defined as a separate restriction on the use of each mechanism or as a single restriction on the use of all three mechanisms.

1.2.5 Schedule for developing rules

In November 1998, parties agreed to a plan of action to develop the necessary rules and guidelines for the three Kyoto Protocol mechanisms by late 2000. The rules for IET can be adopted before the Kyoto Protocol comes into force, but the rules for JI and CDM cannot be formally be adopted until after the Kyoto Protocol comes into force.[20] The Kyoto Protocol is unlikely to come into force before 2000. The Converence of the Parties (COP 6) in late 2000 could recommend rules that subsequently would be formally adopted after the Kyoto Protocol comes into force.

1.3 Sequestration Actions

The ability to use sink enhancement or sequestration actions to help meet the emission limitation commitments of Annex I parties is governed by Articles 3.3 and 3.4 of the Kyoto Protocol. Article 3.3 addresses land use change and forestry actions while Article 3.4 covers all other sink enhancement actions, including soil sequestration.

19. Examples of other types of controversial projects that might be proposed under the CDM include construction of nuclear generating stations rather than proposed coal-fired stations and claims for emission reductions due to government policies, such as an increase in the gasoline tax.

20. Article 17, which covers IET, provides that the relevant principles, modalities, rules and guidelines shall be defined by the COP. Thus they can be adopted before the Protocol is ratified and comes into force. The modalities, rules and guidelines for JI (Article 6.2) and the CDM (Article 12.7), on the other hand, are to be adopted by the COP/MOP. Formally, this can not happen until after the Kyoto Protocol has been ratified and has come into force.

1.3.1 Eligibility of land-use change and forestry actions

Article 3.3 allows carbon sequestered during the commitment period by specified actions to offset greenhouse gas emissions by an Annex I party. The specified actions are "direct, human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990" in an Annex I country. Only the net carbon sequestered during the period 2008–2012 by eligible afforestation, reforestation and deforestation actions can be counted.

Operational interpretation of Article 3.3 raises many questions. What are afforestation, reforestation and deforestation activities? How is the net amount of carbon sequestered to be calculated? What provisions need to be implemented to ensure that the sequestration actions are not offset by leakage elsewhere?[21]

The Intergovernmental Panel on Climate Change (IPCC) is preparing a special report on technical issues related to implementation of Article 3.3. Other aspects of implementation of Article 3.3 are included in the plan of action adopted by COP 4 for completion by late 2000. Thus, the rules governing carbon sequestration through human-induced afforestation, reforestation and deforestation actions will not be known until late 2000 at the earliest.

1.3.2 Eligibility of soil sequestration actions

Article 3.4 provides that the COP/MOP shall "decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories" can be used to offset greenhouse gas emissions by Annex I parties.

Formally then, a decision on whether soil sequestration actions will be allowed and the rules governing such actions cannot occur before the Kyoto Protocol comes into force. However, recommended rules for soil sequestration actions could be adopted by COP 6 in late 2000 for subsequent formal adoption by the COP/MOP.

Regardless of the provisions of Article 3.4, actions to reduce emissions of greenhouse gases from agricultural soils can make a limited contribution to meeting Canada's commitment for 2008–2012.[22] Canada reported net emissions of 7,090 kt CO_2 from soils as part of its inventory for 1990. Actions to reduce these emissions to zero would help meet the 2008–2012 commitment and do not require a decision on the eligibility of soil sequestration actions under Article 3.4. Net CO_2 emissions from soils has declined since 1990 and were 2,480 kt CO_2 in 1995, so the remaining potential for such actions is limited.[23]

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21. Leakage is increased emissions elsewhere as a result of sequestration or emission reduction actions. Examples include increased steel production in (and imports of steel from) non-Annex I parties due to policies to limit greenhouse gas emissions in Annex I countries and increased wood harvesting elsewhere due to actions to protect existing forests. Leakage need not be deliberate.

22. Jacques, Neitzert and Boileau 1997, p. A-3.

23. Ibid.

1.4 Potential Use of the Kyoto Protocol Mechanisms

The Government of Canada can use the Kyoto Protocol mechanisms to help achieve the national commitment regardless of the policies implemented domestically but their use depends on domestic policies.

1.4.1 Potential use by the Government of Canada

The Government of Canada could buy assigned amount or JI emission reduction units from other Annex I Parties. It could also purchase certified emission reduction credits created by CDM projects in developing countries. The purchases of these instruments [24] and their use to help achieve compliance with the national commitment would, of course, be subject to the rules adopted for the mechanisms.

The Government of Canada could also sell surplus assigned amount or approve JI projects that reduce emissions in Canada. Some of the emission reductions achieved by such projects would be exported and reduce Canada's assigned amount accordingly. Such purchases and sales are possible regardless of the policies implemented domestically.

1.4.2 Potential use by individual emission sources in Canada

To meet its national commitment, Canada needs to adopt policies to limit greenhouse gas emissions by individual sources. The ability of a specific source of greenhouse gas emissions to use the Kyoto Protocol mechanisms depends on the domestic policies with which it must comply. Possible domestic policies to manage greenhouse gas emissions fall into four categories:

- domestic emissions trading[25]
- emission fee or tax
- regulations
- other policies.

A Canadian source might wish to purchase assigned amount, JI emission reduction units, or certified CDM credits to help achieve compliance with its domestic obligations. This purchase could occur in three circumstances:

- If the source is a participant in a domestic emissions trading program, it should be allowed to purchase such instruments and to use them toward compliance with its domestic obligations. Thus, a source could provide the regulator with a combination of domestic allowances or credits and Kyoto Protocol instruments equal to its actual emissions to achieve compliance. Title to the Kyoto Protocol instruments would be transferred to the Government of Canada to use them toward compliance with its national commitment.

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24. The term "instruments" or "Kyoto Protocol instruments" is used to refer to assigned amount, JI emission reduction units, or certified emission reduction credits created by CDM projects when the distinction among the mechanisms does not matter.

25. National Round Table on the Environment and the Economy (NRTEE) 1999 describes possible designs for a domestic emissions trading program.

The government would want to ensure that there is no risk of disallowance of some of the Kyoto Protocol instruments due to the liability provisions adopted.[26] The government might also impose limits on the use of such instruments to ensure compliance with the supplementarity provisions in the rules. Otherwise there is no reason why the government should not accept Kyoto Protocol instruments toward compliance in a domestic emissions trading program.

- If the source is subject to an emission tax, it could in principle, be allowed to use the Kyoto Protocol mechanisms to reduce its tax liability. Instead of paying tax on some (or all) of its actual emissions, the source would transfer title to Kyoto Protocol instruments to the Government of Canada for that quantity of emissions. If the tax rate is less than the international market price for Kyoto Protocol instruments, there is no incentive to buy the instruments – paying the tax is less expensive.[27]

  If the tax rate is above the international market price, a source subject to tax can reduce its compliance cost by buying Kyoto Protocol instruments equal to its actual emissions. Then it would pay no tax. If the government depends on the emission tax for revenue, it may restrict the use of Kyoto Protocol instruments to meet its revenue targets.

- If the source is subject to regulations or other policies designed to limit its greenhouse gas emissions, it can use Kyoto Protocol mechanisms for compliance only under specific conditions. The regulation must be formulated in such a way that the quantity of instruments needed to achieve compliance can be calculated. Thus, a regulation that establishes a minimum energy-efficiency standard for refrigerators or acceptable manure handling practices would not allow the use of Kyoto Protocol instruments.

  On the other hand, a regulation that established a corporate average fleet efficiency standard could be structured to allow the use of Kyoto Protocol instruments to achieve compliance. The excess emissions associated with non-compliance with the regulation can be calculated. Transfer of an equivalent quantity of Kyoto Protocol instruments to the Government of Canada would allow it to meet the national commitment despite not meeting the standard required by the regulation.

Now consider a Canadian source that wishes to sell the assigned amount to a source in another Annex I country. Such a sale would be allowed by the Government of Canada only if the seller could demonstrate that it was in compliance with its domestic obligations and hence that the sale would not contribute to non-compliance with the national commitment. Again, there are three circumstances:

- If the source is a participant in a domestic emissions trading program, it should be able to demonstrate whether it is in compliance with its domestic obligations. The quantity of surplus allowances or credits it owns will also be known. Thus it should be possible to allow participants in a domestic emissions trading program to exchange domestic allowances or credits for the assigned amount to sell on the international market.

26. The rules for IET might establish buyer liability, which would reduce the assigned amount purchased by some or all of the buyers from a party whose emissions exceed its remaining assigned amount to bring the seller into compliance. Buyer liability helps keep sellers in compliance with their commitments. But it creates a risk that some of the assigned amount purchased will be discounted or disallowed.

27. For convenience it is assumed that there is a single market price for all instruments. In practice, there may be different prices for different instruments and for a given instrument from different countries.

- If the source is subject to an emission tax, it is not possible to define the surplus allowances or credits it owns. Thus it is not possible for a source subject to an emission tax to earn Kyoto Protocol instruments for sale on the export market.
- If the source is subject to regulations or other policies, it can only sell Kyoto Protocol instruments if the regulations are structured so that it is possible to calculate the surplus reductions the source has achieved.

A Canadian source unable to sell the assigned amount through the IET could seek to structure its emission reduction or sequestration actions as a JI project and so transfer some of the emission reduction units to the foreign partners. A JI project would need to be approved by the Government of Canada. The Government of Canada is likely to approve JI projects only for sources not covered, directly or indirectly, by any domestic policy to reduce greenhouse gas emissions. Failure to do this would likely lead to double counting and so risk non-compliance with the national commitment.

The risk of double-counting reductions from sources whose emissions are covered directly by domestic policies is illustrated by the following example. Assume that manufacturers and importers of combines must meet minimum energy efficiency standards to reduce CO_2 emissions from the fuel used. All combines sold in Canada will meet or exceed the standard. Now assume that a farm cooperative wished to launch a JI project that provided incentives to farmers to buy combines whose energy efficiency was better than the average for new models. It is likely that some of the participants would have purchased the more efficient models in the absence of the JI project. Thus the JI project would count some reductions achieved by the energy efficiency standard. The risk of double counting—reductions due to the regulation being claimed by the JI project—is so high that such a project probably would not be approved.

This risk of double counting is even higher for sources whose emissions are regulated indirectly. Assume that a domestic emissions trading program is implemented for the carbon content of fossil fuels sold in Canada by producers and importers. The actual emission reductions are achieved as a result of energy efficiency and fuel switching measures implemented be energy users in response to the price increases caused by the trading program. A JI project to improve the energy efficiency of buildings runs a significant risk of double counting because it is difficult to determine how much would have been implemented in response to the price increases and how much is due to the JI project.

Assuming that domestic policies apply, directly or indirectly, to most sources of greenhouse gas emissions for efficiency and equity reasons, the potential to host JI projects will be limited.

In summary, the opportunity to use the Kyoto Protocol mechanisms for compliance with domestic policy obligations is greatest for sources covered by a domestic emissions trading program. Access to the Kyoto Protocol mechanisms for compliance purposes is possible under some circumstances for sources subject to an emission tax or to specific types of regulations. The opportunity to sell assigned amount to sources in other Annex I countries is limited to sources covered by a domestic emissions trading program or specific types of regulations. Assuming that domestic policies cover most sources directly or indirectly the opportunity to host a JI project is likely to be very limited.

Section 2: Ability of Emission Sources to Use the Kyoto Protocol Mechanisms

The ability of sources to utilize the Kyoto Protocol mechanisms depends upon the applicable domestic policies. The potential to use the Kyoto Protocol mechanisms is greatest for sources participating in a domestic emissions trading program. The policies likely to be implemented to manage greenhouse gas emissions by the agriculture and agri-food sector are not known.

This section assesses the ability of various sources of greenhouse gas emissions in the agriculture and agri-food sector[28] to use the Kyoto Protocol mechanisms. The assessment is made by considering the suitability of each of these sources to participation in a domestic emissions trading program. This assessment should not be interpreted as a recommendation that each of the sources be addressed through an emissions trading program. It is simply a means of assessing the maximum potential to utilize the Kyoto Protocol mechanisms.

The criteria used to assess whether a source is suitable for inclusion in a domestic emission trading program are discussed first.

2.1 Criteria for Determining Whether a Source is Suitable for Inclusion in a Domestic Emissions Trading Program

An emissions trading system with a government-imposed cap on aggregate emissions by participants can be applied to the actual emissions at the point of release to the atmosphere (emission rights trading) or to a substance that ultimately is released to the atmosphere as a greenhouse gas (substance trading). With an emission rights trading system, it must be possible to measure the actual emissions accurately and reliably. This measurement may require costly monitoring systems, which would limit participation in the trading system to larger sources that could afford such equipment. With a substance trading system, it must be possible to measure the quantity of the substance purchased or sold. This measurement is usually done from administrative records, so the costs are relatively low.

28. See Appendix A for a discussion of the sources of greenhouse gas emissions from the agriculture and agri-food sector in Canada.

To be well suited to a trading system with a government-imposed cap, a source of greenhouse gas emissions in the agriculture and agri-food sector is considered if it satisfies five criteria :

- It covers a relatively large share of the target emissions.
- It has enough participants to create a competitive market, at least 15, none of which has a market share of more than 25 percent.
- It has a sufficiently small number of participants to be administratively feasible, less than 2,500.
- It allows emissions (substance use) to be monitored or calculated with a reasonable degree of accuracy.
- It covers the sources with a range of different control costs so that there are economic gains from trading.

The range of control costs typically grows as the number of participants increases. Incorporating different categories on greenhouse gas emissions, say energy-related CO_2 emissions and N_2O emissions related to fertilizer use, into a single trading program also tends to ensure that participants have different control costs. Where a particular source category has a small number of participants, concerns about market power can be addressed by including them in a larger program combining a variety of sources.

Sources that are not well suited to a trading system with a government-imposed cap may lend themselves to credit trading. Credit trading also can be applied to the actual emissions or to substances that ultimately are released to the atmosphere as greenhouse gases. Credits are created by reducing emissions (substance use) from a specified baseline. Credits can be used to achieve compliance if actual emissions (substance use) exceed a specified baseline. Credits can also be created by increasing sequestration.

A source of greenhouse gas emissions in the agriculture and agri-food sector is considered to be well suited to a credit trading if it satisfies three criteria:

- Actual emissions (substance use) or sequestration can be measured or calculated with reasonable accuracy.
- A reasonable baseline of emissions (substance use) or sequestration that would have occurred in the absence of the actions implemented can be defined.
- The credits can meet the criteria established, such as real, measurable, additional and surplus.

It is assumed that credits will be traded in the same market as the allowances for a trading program with a government-imposed cap, so additional criteria relating to the number of participants and the potential for market power are not needed.

2.2 Carbon Dioxide Emissions from Fossil Fuel Use

Fossil fuel use is responsible for over 75 percent of total greenhouse gas emissions in Canada. Thus, CO_2 emissions associated with fossil fuel use need to be part of any policy to meet a commitment to limit Canada's greenhouse gas emissions. The agriculture and agri-food sector is responsible for only a small fraction of total fossil fuels use in Canada. In the sector, fossil fuels are used on farms, in food processing, and in transporting food products. Emissions from fossil fuel use in the sector are likely to be addressed through policies aimed at limiting greenhouse gas emissions from fossil fuel use generally.

Energy-related greenhouse gas emissions lend themselves well to emission trading. Various emissions trading designs are possible to address energy-related greenhouse gas emissions. Two proposals are most common:

- an emissions trading system for the carbon content of fossil fuels applied to producers and importers with a government-imposed limit on the amount of carbon available for fuels consumed in Canada
- an emissions trading system with a cap on aggregate emissions by large industrial sources, with emissions by other sources being addressed through other policies.

A carbon-content trading system would cover over 90 percent of total energy-related greenhouse gas emissions and involve between 500 and 1,000 companies.[29] To calculate the carbon content, periodic testing of crude oil, raw natural gas and coal is necessary. This testing is already done. The carbon content of refined petroleum products, natural gas liquids, and processed natural gas can be calculated from the product specifications. Thus, the coverage of total emissions (>90 percent) is good, the number of participants (500–1000) is in the acceptable range, and the carbon content can be measured accurately at reasonable cost.

Under a carbon-content trading system, prices of fossil fuels downstream of the trading system rise. Energy users react to the price increases to implement energy efficiency and conservation measures and switch to less carbon-intensive fuels. A large number of energy efficiency, energy conservation, and fuel-switching measures are available with widely differing costs, thus meeting the criterion of differences in control costs across participating sources.

Under a carbon-content trading system, energy users in the agriculture and agri-food sector would not participate in the trading system. They would face higher prices for energy and hence would have a financial incentive to implement energy efficiency, conservation and fuel switching measures,[30] thus reducing energy-related greenhouse gas emissions from the sector. There would be no opportunity for the agriculture and agri-food sector to use the Kyoto Protocol mechanisms to manage its fossil fuel-related CO_2 emissions.

29. National Round table on the environment and the Economy (NRTEE) 1999, Table 2.1, p. 12 and pp. 43-54.

30. In addition to fossil fuel prices, electricity prices would rise where electricity is generated from fossil fuels. If electricity generation is deregulated, electricity prices in regions supplied by non-fossil sources could rise as well if the marginal supply is a fossil-fired source.

An emissions trading system for large industrial sources would require other policies to manage emissions by smaller sources. Such a system would include about 1,000 to 1,200 industrial facilities, electric utilities, airlines and railways. It would cover about 45 percent of total greenhouse gas emissions.[31] Depending upon the facility, monitoring equipment or calculations based on fossil fuel use would be used to determine emissions. Thus, this system also meets the criterion for an administratively feasible number of participants.

A trading system for energy-related emissions by large industrial sources would exclude the agriculture and agri-food sector except for the largest food processing plants. The rest of the fossil fuel-related CO_2 emissions from the sector would be addressed using other policies which do not lend themselves to utilizing the Kyoto Protocol mechanisms.

In summary, greenhouse gas emissions due to fossil fuel use are well suited to some form of emissions trading. The trading system for fossil fuel-related CO_2 emissions could be implemented upstream from the agriculture and agri-food sector, or it could include large food processing plants as participants. Participants in the emissions trading system could use the Kyoto Protocol mechanisms to reduce their compliance costs and hence mitigate downstream price increases. All other sources in the sector would face energy price increases or regulations to encourage emission reductions.

2.3 Nitrous Oxide Emissions Due to Fertilizer Use

N_2O emissions due to fertilizer use depend upon factors such as the type of fertilizer, rate of fertilization, soil factors (oxygen supply, water content, temperature, structure, organic matter content, and nitrate concentration), crops fertilized, tillage, and rotations. Emissions can be estimated by applying average loss coefficient to the nitrogen content of different types of fertilizers. Since N_2O emissions vary due to the factors mentioned, the average loss coefficients are uncertain.

Measuring actual N_2O emissions on individual farms from fertilizer use would not be feasible as the basis for an emission trading program. The monitoring costs would be too high and the number of participants would be too large.

However, it should be possible to address N_2O emissions due to fertilizer use through a trading program applied to manufacturers and importers of fertilizers. These firms could be required to hold allowances equal to the quantity of each type of fertilizer sold in Canada multiplied by the appropriate loss coefficient.[32] Exports of fertilizer would be exempt.

Such a program would cover almost all N_2O emissions due to fertilizer use. The number of participants (fertilizer manufacturers and importers) is reasonable. Monitoring would be based on administrative records such as production records, sales invoices, import and export documents. The added administrative burden on participants would be small. The agency responsible for administering the trading program would need to audit reports periodically to ensure compliance.

31. National Round table on the environment and the Economy (NRTEE) 1999, Table 2.1, p. 12 and pp. 55-68.

32. The loss coefficients could be expressed in terms of CO_2 equivalents to facilitate trading with other sources.

The main concern about regulating N_2O emissions due to fertilizer use in this manner is the accuracy of the emission coefficients. More research might be required to support the

coefficients adopted. On the other hand, any other approach to managing these emissions will also be subject to some, perhaps much more, uncertainty.

The implication for the agriculture and agri-food sector is that N_2O emissions due to fertilizer use would involve fertilizer manufacturers and importers. They would be able to utilize the Kyoto Protocol mechanisms to reduce the cost of compliance or to increase Canadian sales of nitrogen fertilizers. Farmers would face higher prices for nitrogen fertilizers. The higher prices would provide an incentive to use fertilizers more efficiently and effectively.

2.4 Methane Emissions from Enteric Fermentation and Manure

Development of policies to control CH_4 emissions from enteric fermentation and livestock manure is a daunting challenge.[33] The emissions originate with millions of animals on thousands of farms. The emissions vary with many factors and are difficult to measure.

A trading system for dealing with CH_4 emissions from enteric fermentation and manure was considered, and rejected, in Australia.[34] That trading system would require purchasers of agricultural products to hold allowances for the emissions associated with the products purchased. Thus meat packing plants would be required to hold allowances equal to the average CH_4 emissions from a steer or hog. Dairies and cheese manufacturers would be required to hold allowances equal to the emissions associated with a litre of milk.

The main reasons for rejecting this approach are that the emissions associated with various agricultural products are highly variable and the system does not provide the individual farmer with an incentive to implement emission reduction measures. The variability can be addressed to some extent by defining a larger number of farm products, by distinguishing range steers from feedlot steers for example. But this distinction increases the complexity of the system and may make enforcement more difficult; feedlot steers would need to be distinguished from range steers at the time of purchase.

Farmers can be given an incentive to implement measures to reduce the emissions by enabling them to create credits for actions that reduce emissions from the levels incorporated into the emission coefficients. Assume that the coefficient for milk reflects CH_4 emissions from a lagoon system for manure handling. A farmer that installs a different manure handling system to reduce emissions could claim credits for the lower emissions. The same principle would apply to the use of feed supplements and other measures to reduce the emissions. Farmers could transfer the credits to the producers to make their products more attractive or sell them to any participant in the trading program to help recover the cost of the measures implemented.

33. New Zealand Ministry for the Environment 1998 indicates that these emissions account for 43.1 percent of that country's total greenhouse gas emissions. It excludes them from the design of a domestic emission trading program.

34. Hinchy, Fisher and Graham 1998, pp. 33-35. New Zealand also rejected this approach for the same reasons (personal communication with Stuart Calman, Ministry for the Environment, New Zealand, October 1998).

A trading system involving purchasers of agricultural products would face another difficulty in Canada due to international trade in livestock. Under the Kyoto Protocol, Canada is responsible for the emissions by livestock raised in Canada. The emissions associated with exported livestock and products, for which Canada is responsible, would not be covered by the trading system. The emissions associated with imported livestock and products purchased by Canadian processing plants would be covered by the system even though they are not included in Canada's emission inventory. Thus, as a result of international trade in livestock and products, the emissions covered by the trading program could differ significantly from the emissions Canada is responsible for under the Kyoto Protocol.

In summary, CH_4 emissions from enteric fermentation and livestock manure could be addressed by enabling farmers to earn credits for implementing specified measures to reduce the emissions. Such a credit system could operate alone or as part of a trading system that required processing plants to hold allowances for the emissions associated with the products they purchased. In either case farmers would not be required to purchase credits. They would sell their credits to participants in the trading program to help finance the measures implemented. They could also convert the credits to assigned amount and sell them in other Annex I countries.[35] The Canadian price is likely to be equal to or higher than the international price so there would be little incentive to sell the credits abroad.[36]

2.5 Leakage of Hydroflurocarbons

Canada's only mandatory emission trading program is used to manage ozone-depleting substances. The program was introduced in 1993 to help manage the phase out of chlorofluorocarbons (CFCs) and methyl chloroform. It was expanded to cover methyl bromide in 1995 and HCFCs in 1996. Imports of new CFCs and methyl chloroform are now illegal, so the trading program no longer covers these substances.

The regulated ozone-depleting substances (HCFCs and methyl bromide) are currently not produced in Canada; all of the products used in Canada are imported. Canada's trading program for ozone-depleting substances requires importers to hold allowances for the

35. Conceptually it is possible for implementation of the emission reduction actions to be structured as JI projects financed by organizations in other Annex I countries and that a share of the credits would be transferred to the investors. However, the transactions costs for such arrangements are likely to be higher than those associated with domestic financing and conversion of credits to assigned amount for export.

36. Canada is likely to be buyer under the Kyoto Protocol mechanisms because the marginal cost of emission reduction actions in Eastern European countries and developing countries are likely to be lower than the marginal costs of such actions in Canada. Standard and Poor's DRI 1997, Table 12-2, p. B-62, for example, estimates that Canada would be a net importer of 108.4 $mtCO_2$ in 2010 with emissions trading among Annex I countries. Including the CDM in the analysis would reduce the price and lead to larger imports by Canada.

    Assuming no restrictions on the use of the Kyoto Protocol mechanisms, the price for allowances and credits in Canada would be equal to the international price because Canadians could buy as many allowances as they needed to achieve compliance on the international market. Since Canada accounts for a small share of total Annex I emissions, its purchases would not affect the international price. If the use of the Kyoto Protocol mechanisms is restricted by the supplementarity provisions, the Canadian price would be higher than the international price because Canada would need to implement more, and more costly, emission reduction measures domestically. Thus, there is likely to be little incentive to sell Canadian allowances or credits on the international market under the Kyoto Protocol mechanisms.

amount of each substance imported into Canada. The total number of allowances available for a given year is set by Environment Canada to meet the phase out commitment under the Montreal Protocol. Allowances are distributed free to the participants in proportion to their imports during the base year. There are no restrictions on the transfer of these allowances between companies, although transfers must be approved by Environment Canada to ensure that the quantity transferred is unused and therefore available.

Only a few transfers of CFCs and methyl chloroform allowances took place between 1993 and 1996 for two reasons:

- the small number of companies involved, about 12 for each category of substances
- the high degree of competition among the companies.

Selling allowances to a competitor would enable a competitor to expand its market share. Protecting market share apparently was more important than the revenue from the sale of allowances. The same appears to be true for HCFCs.

Because of the small number of importers (five), methyl bromide allowances were distributed to users (about 130). Users transfer the allowances to the importer when they purchases supplies. In 1995 almost all the allowance holders who were not importers transferred their allowances to importers to cover their purchases. Users retain control over the quantity they will be allocated for future years.

HFCs are substitutes for HCFCs in air conditioning, refrigeration, foam manufacturing and other applications. The companies that manufacture and import HCFCs also manufacture and import HFCs. The existing trading program for ozone-depleting substances could be extended to incorporate HFCs, including HFCs for refrigeration use.

If a trading program for imports (and possible production) of HFCs were integrated with a larger trading program for greenhouse gases, importers would be able to purchase allowances from other participants. Competitors would not be restricted to buying allowances from each other. Rather they could buy from (and sell to) companies participating in the program due to their fossil fuel-related CO_2 emissions or the use of SF_6.

The implication for the agriculture and agri-food sector is that emissions due to HFC use in refrigeration are likely to be addressed through a trading program that applies to importers (and producers) of these substances. It is the importers (and producers) of HFCs, rather than sources in the agriculture and agri-food sector that use HFCs in refrigeration systems, that will be able to utilize the Kyoto Protocol mechanisms. Sources in the agriculture and agri-food sector will face higher prices for HFCs and possibly regulations governing HFC use. Access to the Kyoto Protocol mechanisms by the importers will mitigate the price increases.

2.6 Emissions from Wastewater, Landfills and Composting

Some food and beverage processing plants treat, or pre-treat, their wastewater. Some also compost organic wastes rather than send them to landfills. To the extent that processing plants have, or are required to establish, wastewater treatment, landfill or composting facilities, they could be subject to policies to limit the associated greenhouse gas emissions. These facilities require CH_4 collection systems, which are probably uneconomic for small landfills but feasible for wastewater treatment plants and composting facilities.

Wastewater treatment plants, landfills and composting facilities where collection systems can be installed could be included in an emission trading program. CH_4 would be collected and used or flared. A participating source could earn allowances or credits for some fraction of the reduction in CO_2 equivalent emissions achieved by converting CH_4 to CO_2.[37] To reduce further the greenhouse gas emissions associated with these wastes, processing plants could be required to send organic wastes to composting facilities rather than landfills. Composting facilities could then be required to use aerobic, rather then anaerobic, processes.[38]

Municipal and commercial wastewater treatment facilities, landfills and composting facilities are likely to be subject to similar requirements to collect and use or flare CH_4 and to use aerobic composting. Such requirements could lead to municipal regulations to pre-treat wastewater and to separate organic wastes for composting. It could also lead to higher sewage treatment surcharges and higher landfill tipping fees. These costs and regulations would affect processing plants that do not treat their own wastewater and organic wastes.

In short, food and beverage processing plants that treat their own wastewater and organic wastes, or are required to do so in the future, could be part of a domestic emission trading program. They could earn credits for the reduction in CO_2 equivalent emissions that result from the capture and use or flaring of CH_4. The credits could be sold to other participants in the trading program. In principle they could also be sold to entities in other Annex I countries under the Kyoto Protocol mechanisms, although as discussed earlier, the price in Canada is likely to be equal to or higher than the international price.

2.7 Credits for Carbon Sequestration

Two carbon sequestration options are available to the agriculture and agri-food sector: afforestation or reforestation of marginal agricultural lands and soil sequestration.

2.7.1 Afforestation or reforestation

Article 3.3 of the Kyoto Protocol allows carbon sequestered during the 2008–2012 commitment period as a result of direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990 to count toward meeting the national commitment. The rules governing such sequestration activities remain to be developed.

Article 3.3 suggests that the carbon sequestered during the 2008–2012 period as a result of planting trees on marginal agricultural lands could earn credits toward meeting Canada's national commitment.[39] Carbon lost through deforestation must be offset against the carbon

37. To meet the national commitment to reduce greenhouse gas emissions, all sources would have an obligation to reduce their emissions, in this case CH_4 emissions. Capturing CH_4 emissions, which have a global warming potential (GWP) of 21, and using CH_4 as an energy source or flaring it converts the carbon to CO_2, which has a GWP of 1. Thus, the CO_2 equivalent emissions are reduced from 21 to 1; a 95 percent reduction. This reduction may be more than the reduction obligation imposed on other sources, so these sources could be allowed to earn allowances or credits for the difference between the reduction achieved (95 percent) and the reduction obligation needed to meet the national commitment.

38. Aerobic processes also reduce odour.

39. Note that only carbon sequestered through human-induced activity qualifies. Thus, natural forest regeneration on idle land would not qualify; the trees need to be planted.

sequestered through afforestation and reforestation. Thus credits can only be awarded for afforestation and reforestation if entities that engage in deforestation activity are required to purchase credits for the carbon released.

2.7.2 Sequestration in agricultural soils

It is not yet clear whether carbon sequestration in agricultural soils will be accepted as a compliance option under Article 3.4 of the Kyoto Protocol. Canada and the United States are seeking to have carbon sequestration in agricultural soils included as an option for compliance with Kyoto Protocol commitments. If it is accepted, parties will need to agree on the types of sequestration actions allowed and the procedures for calculating the carbon sequestered.

Soil organic carbon in permanently cropped fields can be increased through six management practices:

- increased return of organic materials to the soil
- decreased periods of fallow
- use of perennial and winter cover crops
- reduced tillage
- erosion control
- agroforestry.

To include soil sequestration in a domestic emissions trading program, individual farmers would need to demonstrate that they have implemented eligible management practices for a sustained period and that the carbon content of the soil has increased as a result.[40] Credits for the quantity of carbon sequestered (denoted in tonnes of CO_2 equivalent emissions) would be issued to the farmer. The credits could then be sold to participants in the domestic emissions trading program with emission reduction obligations.[41]

Since the rules for sequestration activities remain to be developed, any discussion of how such activities would be organized is necessarily speculative. It may be attractive for individual farmers to document the carbon sequestered and sell the resulting credits. Organizing groups of farmers to engage in sequestration actions may offer advantages by reducing monitoring costs, providing better access to monitoring or trading expertise, or access to capital. Organizing groups of farmers to sequester carbon is already happening in Costa Rica and Australia for forest sequestration actions and is under negotiation for soil carbon sequestration.[42]

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40. Several of these practices are already becoming increasingly prevalent. As a result the internationally agreed rules for crediting carbon sequestration in soils might establish a baseline involving increased adoption of these practices. Credit for carbon sequestration in soils would then be limited to sequestration in excess of this rising baseline. This is equivalent to the requirement for JI and CDM projects that the emission reductions be "additional" to those that would occur in the absence of the project.

41. In principle they could also be sold to entities in other Annex I countries under the Kyoto Protocol mechanisms, although the price in Canada is likely to be equal to or higher than the international price.

42. On April 24, 1998 the government of Costa Rica announced that one million tonnes of CO_2 equivalent carbon sequestration had been certified by SGS Forestry. To sequester carbon the government established an organization that contracts individual landowners to implement specified afforestation, reforestation and forestry protection measures.

In summary, credits for carbon sequestered in agricultural soils, or through afforestation and reforestation offer the best opportunity for the agriculture sector to participate in domestic emission trading. However, the eligible sequestration measures and the rules governing credit creation remain to be agreed internationally.

2.8 Ability to Use the Kyoto Protocol Mechanisms

The ability of the agriculture and agri-food sector to use the Kyoto Protocol mechanisms depends upon the domestic policies adopted to meet Canada's emission reduction commitment. It is useful to distinguish the ability to use the Kyoto Protocol mechanisms for compliance with domestic obligations and the ability to sell credits or allowances to other Annex I countries using the Kyoto Protocol mechanisms.

2.8.1 Ability to purchase mechanisms to help achieve domestic compliance

The government should be willing to allow participants in a domestic emissions trading program to use valid instruments from any of the Kyoto Protocol mechanisms to help achieve compliance.[43] In other words, a participant in the domestic emissions trading program could provide the government with domestic allowances, credits created by domestic sources, or valid Kyoto Protocol instruments equal to its actual emissions to achieve compliance.[44] The Kyoto Protocol instruments increase Canada's assigned amount, so their use by a participant in the trading program leaves Canada's compliance situation unchanged.[45]

The ability to use the Kyoto Protocol mechanisms for compliance purposes will be limited to participants in a domestic trading program required to hold allowances, credits or Kyoto Protocol instruments equal to their actual emissions of (or sales of a substance that is ultimately released as) a greenhouse gas. Such a domestic trading program is likely to include few, if any, sources in the agriculture and agri-food sector:

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42. (contd.) Australian Plantation Timber Ltd. raised A$20 million in 1998 to invest in afforestation and reforestation activities. Australian Plantation Timber plans to sell credits earned through carbon sequestration.

    GEMCo, a consortium of Canadian companies that wish to demonstrate industry leadership in developing voluntary and market-based approaches to greenhouse gas emissions management, is negotiating a contract to purchase credits created through soil carbon sequestration from the Iowa Farm Bureau. The Bureau would contract with individual farmers to implement and sustain farming practices to promote carbon sequestration. At various points during the life of the contract the quantity of carbon sequestered would be calculated. GEMCo would pay farmers, through the Iowa Farm Bureau, for the carbon sequestered.

43. The term "instrument" is used to mean assigned amount acquired through international emissions trading, emission reduction units from JI projects, and certified emission reduction credits from CDM projects.

44. Actual emissions could mean the amount of carbon in the fuel produced or imported, the quantity of HFCs imported, the estimated N_2O emissions attributed to fertilizer sold in Canada, as well as actual emissions of greenhouse gases.

45. Of course, the instruments must be valid. The liability and supplementarity rules could affect whether particular instruments are valid and can be used by Canada. Thus, the federal government might establish rules and a review procedure for international instruments used for domestic compliance.

- Food processing plants could be included in the domestic emissions trading program, depending upon the approach used to address energy-related CO_2 emissions some large. Otherwise the trading program would not include any sources in the agriculture and agri-food sector.

- Food processing plants with wastewater treatment, landfill or composting activities could be required to participate in the domestic emissions trading program.

- Enteric fermentation and livestock manure emissions could be addressed by requiring processing plants to hold allowances for the emissions associated with the products they purchase, although this approach is problematic.

Fertilizer manufacturers and importers could also be included in a domestic trading program to address N_2O emissions associated with fertilizer use. HFC importers are likely to be part of a domestic cap and trade program for greenhouse gases.

It is very unlikely that individual farmers would be required to be part of a domestic trading program for greenhouse gas emissions.

The ability to use Kyoto Protocol instruments is important to participants in the domestic emissions trading program because it assures Canadian firms that their marginal cost of compliance will be no higher than that faced by competitors in other Annex I countries. Minimizing the cost of compliance is important for all Canadians because the cost of compliance is reflected in the prices of the products they sell. Thus, access to Kyoto Protocol instruments is important to keep fossil fuel and fertilizer price increases to a minimum.

2.8.2 Ability to export allowances or credits through the Kyoto Protocol mechanisms

The Government of Canada could allow any person or entity that owns valid allowances or credits and is in compliance with its domestic obligations to convert those allowances or credits to an equivalent quantity of assigned amount for export.[46]

Both farmers and food processing plants could be allowed to create credits under the policies adopted to meet Canada's national commitment. Specifically, farmers might be able to create credits for actions to reduce emissions from enteric fermentation and livestock manure, afforestation and reforestation, and, possibly soil sequestration. Food processing plants might be able to create credits by reducing emissions from treatment of their wastes.

In principle, these credits and surplus allowances held by participants in a domestic trading program could be sold internationally through the Kyoto Protocol mechanisms. But the Canadian price is likely to be equal to or higher than the international price, so there would be little incentive to export the credits or allowances.

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46. This conversion assumes that IET is used. Credit creation actions could also be structured, with government approval, as JI projects. Selling surplus allowances from a domestic cap and trade program through IET is likely to involve lower transaction costs than structuring the measures to generate the surplus allowances as a JI project. The transaction costs involved in creating credits under a domestic program, converting them into assigned amount, and exporting them through IET are likely to be no higher, and possibly lower, than structuring the same action as a JI project. Thus to simplify the presentation, it is possible to limit the discussion to exports of domestic allowances or credits through the IET mechanism. In practice, some credit exports could be structured as JI projects. Recall that Canada cannot host CDM projects.

Most studies indicate that Canada is likely to be a buyer under the Kyoto Protocol mechanisms because the marginal costs of emission reduction actions in Eastern European countries and developing countries are likely to be lower than the marginal costs of such actions in Canada. Assuming no restrictions on the use of the Kyoto Protocol mechanisms, the price for allowances and credits in Canada would be equal to the international price because Canadians could buy as many allowances as they needed on the international market.

If the use of the Kyoto Protocol mechanisms is restricted by the supplementarity provisions, the Canadian price would be higher then the international price because Canada would need to implement more and more costly, emission reduction measures domestically. Thus, the Canadian price would be equal to or higher than the international price and there is likely to be little incentive to sell Canadian allowances or credits on the international market under the Kyoto Protocol mechanisms.

In summary, Canada is expected to be a net importer of Kyoto Protocol instruments, so access to the Kyoto Protocol mechanisms to allow exports of allowances or credits may not be very important. The price for the allowances or credits is likely to be at least as high in Canada as on the international market. However, individual farmers and food processing plants might be able to create credits under the domestic policies to limit greenhouse gas emissions. They could then sell those credits on the domestic or international market.

Section 3: Potential Impact of Kyoto Protocol Mechanisms

Section 2 concluded that a domestic emissions trading program to manage greenhouse gases is likely to involve few, if any, sources in the agriculture and agri-food sector. Sources in the agriculture and agri-food sector would face price increases for inputs that give rise to greenhouse gas emissions. These price increases would provide an incentive to implement measures to reduce emissions from the agriculture and agri-food sector.

Sources in the agriculture and agri-food sector might be allowed to create credits through emission reduction or sequestration actions. In principle those credits could be exported using the Kyoto Protocol mechanisms. In practice prices are likely to be at least as high in Canada as on the international market so the credits are likely to be sold domestically.

Under these conditions access to the Kyoto Protocol mechanisms by sources in the agriculture and agri-food sector would be minimal. However, access to the Kyoto Protocol mechanisms by participants in the domestic emissions trading program will be important to the agriculture and agri-food sector because such access reduces the cost of compliance and hence the price increases faced by farmers and food processors.

This section addresses a number of issues related to the impact of the Kyoto Protocol mechanisms to the agriculture and agri-food sector.

3.1 Relevance to Different Emission Sources in the Sector

The emissions limitation commitment established by the Kyoto Protocol covers six gases emitted by a wide range of sources.[47] To meet its commitment Canada will need to implement domestic policies designed to limit emissions of almost all these gases/sources. Thus, almost all sources of greenhouse gas emissions in the agriculture and agri-food sector are likely to be regulated directly or indirectly. Because of the large number of sources involved, governments will probably look for policies that control emissions by farm sources

47. The six gases are CO_2, CH_4, N_2O, SF_6, HFCs and PFCs (see page 1).

indirectly. N_2O emissions associated with fertilizer use can be regulated indirectly, for example, by including fertilizer manufacturers and importers in an emission trading program.

Food processing plants are larger and less numerous. Some emissions limitation policies might apply directly to food processing plants. Alternatively, some or all of the greenhouse gas emissions associated with food processing—fuel use, HFC leakage and waste processing—could be addressed indirectly through fuel suppliers, HFC importers, wastewater treatment plants and landfills.

The ability to buy allowances or credits through the Kyoto Protocol mechanisms to reduce the cost of compliance with domestic policies is relevant only to participants in a domestic emissions trading program.[48] Thus the ability to buy allowances or credits through the Kyoto Protocol mechanisms is likely to be directly relevant at most for larger food processing plants, HFC importers, and fertilizer manufacturers and importers. Sources regulated indirectly benefit indirectly from use of the Kyoto Protocol mechanisms by participants in a domestic emission trading program through smaller price impacts.

The ability to sell allowances or credits through the Kyoto Protocol mechanisms is unlikely to be a significant benefit to the agriculture and agri-food sector. Domestic policies may allow credits to be created through afforestation or reforestation, soil sequestration, or livestock emission reduction actions.[49] But Canada is expected to be a net importer of Kyoto Protocol instruments from other countries. Thus, the domestic price is expected to be at least as high as the international price for domestically created credits. Hence, access to the Kyoto Protocol mechanisms for the purpose of selling credits internationally is unlikely to yield significant benefits for the sector.

In summary, access to the Kyoto Protocol mechanisms is most important for sources subject to domestic emissions trading programs as a means of reducing compliance costs. Few, if any, sources in the agriculture and agri-food sector are likely to be subject to such policies. Lower compliance costs are important to the sector because this minimizes the price impacts downstream of the regulated entities. Access to the Kyoto Protocol mechanisms to export credits or allowances is not expected to be important because the domestic price is expected to be at least as high as the international price.

3.2 Relevance to Sequestration Options in the Sector

Article 3.3 of the Kyoto Protocol allows countries to count sequestration during the 2008–2012 commitment period resulting from direct human-induced land-use change and forestry actions implemented since 1990 toward meeting their commitments. The actions are further limited to afforestation, reforestation and deforestation measures. The rules governing these sequestration actions remain to be developed.

48. The participants in a domestic trading program include sources that are subject to standards, which allow the use of credits or allowances to achieve compliance with the standard.

49. Domestic policies concerning credit creation would be expected to match the rules agreed for the use of sequestration actions to help achieve compliance with the Kyoto Protocol commitments. Thus, soil sequestration actions might not be eligible to create credits.

Assuming that rules governing such sequestration activities are adopted, farmers could earn sequestration credits by planting trees on marginal agricultural land. Deliberate tree planting efforts after 1990 could earn credits, but natural forest regeneration could not earn credits. In addition, only carbon sequestered during the period 2008–2012 could earn credits.[50] Given the pattern of carbon sequestration during tree growth, trees planted during, or shortly before, the 2008–2012 period would earn very few credits. Only trees already planted, or planted in the near future, will be able to sequester substantial quantities of carbon during the 2008–2012 period.

Article 3.4 requires the COP/MOP to decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories can be used by Annex I parties for compliance. Thus, whether carbon sequestration in agricultural soils will be allowed is not yet clear.

Estimates of the potential for carbon sequestration in Canadian agricultural soils range from 8–25 mt CO_2 equivalent per year.[51] CHEMinfo Services reports results from the CENTURY model over a 50-year period that estimate annual carbon storage equivalent to 3.4 percent of Canada's present CO_2 emissions, approximately 21,000 mt CO_2 equivalent.[52] Hastie estimates that soil sequestration could meet 6–8 percent of Canada's Kyoto Protocol target without incentives and up to 18 percent with incentives.[53] A reduction of 136 mt CO_2 equivalent from the projected emissions in 2010 is expected to be needed to meet Canada's commitment.[54] Thus, the estimated potential for soil sequestration is 8–11 mt CO_2 equivalent without incentives and up to 25 mt CO_2 equivalent with incentives.

Soil sequestration on this scale would certainly help meet Canada's national commitment, but it would not fundamentally change Canada's compliance strategy. Compliance is estimated to require a reduction of 136 mt CO_2 equivalent from business as usual emissions in 2010. Imports under the Kyoto Protocol mechanisms could amount to more than 100 mt CO_2 equivalent.[55] In short, soil sequestration would not eliminate the need for emission reduction policies in Canada, nor make Canada an exporter, rather than an importer, of Kyoto Protocol instruments.

50. The credits earned would presumably be reduced by the amount of carbon released through deforestation during the same period on the same property. Unless property owners with net deforestation can be forced to purchase credits covering the emissions, the credits earned by afforestation and reforestation activities could be discounted to reflect the net sequestration nationally.

51. Carbon sequestration cannot continue indefinitely. The carbon content of the soil increases until a new equilibrium is established.

52. This section is drawn from CHEMinfo Services Inc. 1998, p. 75.

53. Hastie 1998.

54. Natural Resources Canada 1997, Chart 7.10, p. 75 shows the 1990 emissions as 564 mt CO_2 equivalent and the 2010 emissions as 669 mt CO_2 equivalent. The Kyoto Protocol commitment is 94 percent of the 1990 emissions or 533 mt CO_2 equivalent, so the reduction required from the projected emissions is 669-533 = 136 mt CO_2 equivalent.

55. Standard and Poor's DRI 1997, Table 12-2, p. B-62, for example, estimates that Canada would be a net importer of 108.4 mt CO_2 in 2010 with emission trading among Annex I countries. Including the CDM in the analysis would reduce the price and lead to larger imports by Canada.

Carbon sequestration in agricultural soils, if allowed, could yield annual revenues between $32 million and $1.25 billion to Canadian farmers between 2008 and 2012. Estimates of the world market price for Kyoto Protocol instruments vary widely, ranging from US$3.00 to US$31.50 per tonne CO_2 equivalent (US$11 to US$116 per tonne carbon) or about $4 to $50 (1996 Canadian dollars) per tonne of CO_2 in 2010.[56] When this range is multiplied by the estimate of 8–25 mt CO_2 equivalent per year potential for soil sequestration, the annual revenues are $32 million to $1.25 billion.

Revenue from the sale of soil sequestration credits could be substantial, particularly for larger farms, especially if the price for CO_2 is near the upper end of the range. Spread over all farms in Canada, the annual revenue of $32 million to $1.25 billion averages $130 to $5,250 per farm.[57] Spreading the revenue over prairie farms, since most of the potential for carbon sequestration is for prairie soils, raises the average to $250 to $9,900 per farm. For an 800-hectare prairie farm with a carbon sequestration rate of 0.73 tonnes CO_2 per hectare per year, the revenue from the sale of credits might range from $2,300 to $29,200 per year over a number of years.[58]

In summary, decisions relating to the eligibility of soil sequestration actions and the rules for calculating carbon sequestered through eligible sequestration actions will be important to the agriculture and agri-food sector. But these decisions are independent of the Kyoto Protocol mechanisms. Soil sequestration, then, could yield annual revenues between $32 million and $1.25 billion to Canadian farmers between 2008 and 2012 if allowed under the Kyoto Protocol. Soil sequestration and the associated revenue would continue until a new equilibrium is established.

3.3 How Emissions Trading Might Work in the Sector

One of the considerations in designing an emissions trading program is the trade-off between the share of total emissions covered and the number of participants. At some point adding more participants increases the administrative burden but has little impact on the share of total emissions covered.

The agriculture and agri-food sector is responsible for over 10 percent of Canada's total greenhouse gas emissions. Most of the emissions from the sector are difficult to incorporate into an emissions trading program. In addition, the number of sources, whether animals or farms, is large. It is unlikely, therefore, that a separate emissions trading program for greenhouse gases would be established for the sector.

Canadian policies to limit greenhouse gas emissions could be designed so that few, if any, sources in the agriculture and agri-food sector are required to participate in a national emissions trading program for greenhouse gases. If sources from the sector were required to participate in an emissions trading program, they would likely be larger food processing plants and fertilizer manufacturers and importers.

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56. See Haites 1998a.

57. Statistics Canada 1998, reports the total number of farms in Canada as 238,695 and the total number of farms in the three prairie provinces as 126,749.

58. Hastie 1998 reports the rate of carbon sequestration as 0.73 tonnes CO_2 per hectare per year for cropland and intensively-used range land.

Farms may be able to create credits through afforestation and reforestation, soil sequestration, and actions to reduce emissions from enteric fermentation and livestock manure. The ability to create credits through such actions will depend on the rules adopted internationally and on the domestic programs to manage greenhouse gas emissions. If credits can be created through such actions, the market participant may be an organization that bundles credits created by a number of farmers. GEMCo is negotiating such an arrangement with the Iowa Farm Bureau and similar arrangements exist for forest sequestration actions in Costa Rica and Australia.

3.4 Role of Government

The emissions limitation commitments of the Kyoto Protocol apply to the national governments of Annex I countries. To meet its commitment, the federal government will need to work with the provincial governments to implement policies to limit greenhouse gas emissions because of the constitutional division of authority.

A domestic emissions trading program would be one of a portfolio of policies implemented to meet the national commitment. Some policies would be implemented by the federal government, others by provincial governments, and others jointly by the federal and provincial governments.

In the case of an emissions trading program, governments will determine the type of trading program (allowance or credit) and the sources that are required to participate. Governments will decide how allowances will be distributed (free or by auction) for an allowance trading program and how credits can be created for a credit trading program. Governments will also establish rules governing the operation of the program, including monitoring requirements, reporting requirements, reporting deadlines, and penalties for non-compliance. Finally, governments will audit compliance and enforce penalties for non-compliance.

Since the agriculture and agri-food sector accounts for over 10 percent of Canada's greenhouse gas emissions, policies to limit the emissions by agriculture and agri-food sources can be expected. Governments will consult affected stakeholders when developing policies to limit greenhouse gas emissions. Thus, representatives of the agriculture and agri-food sector will have an opportunity to provide advice to governments on the design of greenhouse gas emissions control policies, including their relationship to the Kyoto Protocol mechanisms.

3.5 Potential Transaction Costs for Different Trading Systems

Transaction costs for different trading systems are difficult to compare.[59] Transaction costs include components that are difficult to observe and usually not reported, such as responses to uncertainty in the rules of the trading program. To achieve an emission reduction target, a credit trading program is usually accompanied by regulations to limit the emissions. Thus, some monitoring, reporting and enforcement costs can be allocated either to the regulations or to the trading program. In contrast, an allowance trading program is generally the principal policy for achieving the emissions target.

59. See Commission for Environmental Cooperation 1997, p. 33 for a discussion of the difficulties of measuring transaction costs for different trading systems. See also Haites 1998b, p. 42 for estimates of the costs of trading under selected emissions trading programs in the United Sates.

Despite these difficulties, it is generally accepted that transaction costs tend to be higher for credit trading programs than for allowance trading programs. Participants in an allowance trading program need only to monitor or to calculate their actual emissions. To create credits a source must document the emissions reduced or sequestered. This documentation involves monitoring actual emissions (sequestration), calculating what emissions (sequestration) would have been in the absence of the action, and getting regulatory approval for the credits.

Transaction costs can be significantly affected by the specific rules of the trading program. Monitoring and reporting requirements, approval processes, and administrative fees can all affect transaction costs. Thus, an efficient credit trading program could have lower transaction costs than a cumbersome allowance trading program.

The emissions trading program designs discussed in Section 2 for energy-related CO_2 emissions, HFCs, and N_2O emissions due to fertilizer use are allowance trading programs. They could be designed so that the transaction costs are relatively low. Credits created through afforestation and reforestation, soil sequestration, and actions to reduce the emissions from enteric fermentation and livestock manure, if allowed, would probably involve relatively high transaction costs for an individual farmer. However, organizing groups of farmers to engage in sequestration actions may offer advantages by reducing monitoring costs, providing better access to monitoring or trading expertise, or access to capital. This organization can be done by farmers or by investors, such as GEMCo.

3.6 Relationship to Supply Management Systems

Some agricultural products, including milk, eggs and poultry, are governed by supply management systems. Typically, producers must hold quota for the quantity produced and the price received is based on the cost of production.

The policies implemented to limit greenhouse gas emissions from the agriculture and agri-food sector are likely to affect prices for inputs, such as energy and fertilizer, purchased by farmers. This affect on price is true for an emission trading program or any other type of domestic policy. The price increases would be reflected in the cost of production calculations for supply-managed products.

In some cases, such as dairy products, it may be possible to create credits through sequestration or emission reduction measures. Then it will be necessary to decide how much revenue from credit creation actions to offset against the cost of production.

In summary, an emissions trading program for greenhouse gases should not affect the basic structure of a supply management system where one exists. Prices of inputs would change and be reflected in the cost of production calculations. Farmers may also be able to earn revenue through credit creation and a decision would need to be made on how much of this revenue to offset against the cost of production.

3.7 Impacts on International Trade of Food Products

Annex I countries will be responsible for limiting greenhouse gas emissions associated with the production, processing and domestic transport of food products under the Kyoto Protocol. All Annex I countries will need to implement policies to limit such emissions.

Different countries are likely to adopt different policies. Regardless of the policy adopted, the result is likely to be an increase in the costs of production. The increase in the cost of production could differ from country to country.[60] Non-Annex I countries will have no emissions limitation commitments during the 2008–2012 period. Producers in non-Annex I countries will not face increases in, and might benefit from lower costs of production.[61] As a result, the comparative advantage of producers in different countries shifts.

Producers in non-Annex I countries should benefit relative to those in Annex I countries. The comparative advantage of different Annex I countries may shift depending upon the policies adopted in each country. The magnitude of the resulting shifts in trade patterns can only be determined through modeling. It will not be possible to predict the policies each Annex I country will adopt, but it should be possible to estimate how sensitive Canada's trade in food products is to cost changes domestically and in other countries.

Trade in food products may be affected, as well, by impacts on the exchange rate due to changes in trade flows for other goods and services or due to international capital flows, including purchases and sales of Kyoto Protocol instruments. A model of international trade in food products then, may not be sufficiently comprehensive to consider all of the mechanisms through which the Kyoto Protocol could affect trade in food products.

In summary, policies to limit greenhouse gas emissions in Annex I countries will shift comparative advantage in the production of various food products. The impact of these shifts can only be estimated with the aid of models. Since the impacts depend on the policies adopted by different countries, which are not known, it is possible only to estimate how sensitive Canada's trade in food products is to cost changes domestically and in other countries.

3.8 Impacts on Competitiveness in the Sector

An analysis of the impacts of the Kyoto Protocol on the competitiveness of Canada's agriculture and agri-food sector is similar to an analysis of its impacts on international trade in food products. The impacts on competitiveness depend on the policies adopted in Canada and the policies adopted by other countries. The impacts will depend on the policies that affect the emissions by the agriculture and agri-food sector, but they can also depend on the exchange rate response to changes in trade flows in other sectors and international capital flows.

In principle, the best policy strategy for Canada, given the uncertainty surrounding the policies likely to be implemented by other countries, is to meet the national commitment at the lowest cost. A domestic emission trading program that incorporates a large share of the total emissions, keeps administrative costs low, and provides easy access to the Kyoto Protocol mechanisms, should minimize the cost of meeting Canada's national commitment.

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60. The difference could be due to differences in the policies adopted, say emissions trading rather then regulations, or to associated adjustment measures, such as redistribution of the revenue from an auction of allowances.

61. Compliance with the emissions limitation commitments of Annex I countries is expected to reduce the world demand for petroleum products and so reduce the world price for crude oil. The emissions limitation policies in Annex I countries must offset the effects of this price increase to meet their commitments. But non-Annex I countries benefit from the lower price.

The impact of the Kyoto Protocol on the competitiveness of the agriculture and agri-food sector can only be estimated with the aid of models. The models should address all sectors of the economy as well as international capital flows, including purchases and sales of Kyoto Protocol instruments. Since the impacts depend on the policies adopted by different countries, which are not known, it is possible only to estimate how sensitive Canada's agriculture and agri-food sector is to cost changes domestically and in other countries.

3.9 Relationship to Policies for Other Sectors

To meet the national emissions limitation commitment, it will be necessary to implement policies to limit emissions by almost every source in Canada. A domestic emission trading program allows the commitment to be met at a lower cost than using other policy instruments.[62]

In an emissions trading program, the cost savings stem from differences in the marginal cost of control across participating sources. Increasing the number of participants and the diversity of the sources in the trading program tends to increase the variation in marginal control costs and so increase the benefits from emission trading. Thus, including the agriculture and agri-food sector in an emission trading program with all other sources of greenhouse gas emissions will help to reduce compliance costs.

Considering all emission sources simultaneously in the design of the domestic policy also enables the trading program to cover a large share of the total emissions with a minimum number of participants. This consideration may mean that some or most of the emissions in the agriculture and agri-food sector are addressed indirectly rather than through direct participation in an emissions trading program.

In summary, an emissions trading program that covers as many sources of greenhouse gas emissions as feasible, directly or indirectly, yields the largest cost savings. Incorporating the emissions from the agriculture and agri-food sector into a national emissions trading program would achieve this result. Since the sector accounts for over 10 percent of total greenhouse gas emissions, implementing a separate trading program for the agriculture and agri-food sector would appear to be inefficient and undesirable.[63]

3.10 Potential Issues for Future Quantitative Analysis

Quantitative analysis of the following six issues would enhance understanding of the impacts of policies to limit greenhouse gas emissions on the agriculture and agri-food sector:

- Impacts on fertilizer prices, fertilizer use and agricultural output assuming N_2O emissions due to fertilizer use were covered by a trading program for the nitrogen content of fertilizer, adjusted by an emissions factor, sold in Canada.

62. In principle, an emission tax could meet the national commitment as efficiently as an emissions trading program.

63. A separate trading program might be economically advantageous for the agriculture and agri-food sector if the marginal cost for emission reduction and sequestration measures were lower than for other sources. This approach, however, might be considered unfair by other sectors.

- Impacts on energy prices, farm energy use, and production costs for different agricultural products assuming the energy-related CO_2 emissions were covered by a trading program for the carbon content of fossil fuels sold in Canada.
- Costs of alternative measures to limit enteric fermentation and livestock manure emissions.
- Supply curves for carbon sequestration through afforestation, reforestation, and soil sequestration during 2008–2012 due to direct human-induced activity.
- Impacts on energy prices, energy consumption, waste treatment and disposal costs, and production costs for food and beverage industries assuming the energy-related CO_2 emissions were covered by a trading program for the carbon content of fossil fuels sold in Canada.
- Impacts on the competitiveness of the Canadian agriculture and agri-food sector, including trade in food products, due to compliance with the Kyoto Protocol.

3.11 Possible Frameworks for Quantitative Analysis of Issues Identified

Quantitative analysis of an issue requires a suitable model or framework. While many models of the agriculture and agri-food sector, the Canadian economy, and the global economy are available, it is possible, indeed likely, that none is ideally suited to the analysis of a particular issue. Nevertheless, it is usually possible to gain insights into an issue through the use of a combination of models.

Quantitative analysis of the issues identified in the previous section is possible using five available models:

- Canadian Regional Agriculture Model (CRAM) for analysis of impacts on agricultural output
- CENTURY model for soil sequestration
- Macroeconomic models of the Canadian economy, such as IFSD, National Energy Board, Conference Board of Canada, Informetrica, DRI, and WEFA, to estimate the impacts on energy prices
- A model of international agricultural trade, such as the Basic Linked System (BLS)
- Global models with a Canadian module, such as G-Cubed, AIM, MegABARE, Charles River Associates, and SGM, to assess the impacts on competitiveness, and of these, G -Cubed is the only model that explicitly incorporates international capital flows.

Most of the macroeconomic and global models do not include much detail on the agriculture and agri-food sector. Therefore studies of the impacts of price changes, competitiveness, and food trade will probably require linked or coordinated analyses involving such models and models of the agriculture and agri-food sector.

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Appendix A: Greenhouse Gas Emissions by the Agriculture and Agri-Food Sector

The ability of the agriculture and agri-food sector to utilize the Kyoto Protocol mechanisms depends on the domestic policies adopted for the sector. This appendix summarizes the emissions of greenhouse gases by the agriculture and agri-food sector and opportunities for reducing the emissions. It provides a context for the discussion of possible domestic policies to manage greenhouse gas emissions from the agriculture and agri-food sector in Section 2.

Some sources of greenhouse gas emissions by the agriculture and agri-food sector, such as enteric fermentation, livestock manure, fertilizer use and soils, are reported separately in the national inventory. For other sources of greenhouse gas emissions, such as HFC leakage, wastewater treatment, landfilling and composting, the agriculture and agri-food sector is not reported separately. Estimates of emissions are provided where they could easily be developed.

Each category of greenhouse gas emissions by the agriculture and agri-food sector is described briefly below.

A.1 Fossil Fuel Use on Farms

Combustion of fossil fuels (coal petroleum products and natural gas) produces CO_2, and much smaller emission quantities of CH_4 and N_2O. Various fossil fuels are used on farms for residential purposes (cooking, water heating, space heating) and for business purposes (fuel for tractors and combines, heating and drying applications, generators and other equipment). A small amount of fossil fuel is also used for non-energy purposes, mostly as lubricants and solvents.

International and domestic emissions inventories attribute the emissions to the source that releases it to the atmosphere. Thus the emissions attributed to the agriculture and agri-food sector is due to combustion and evaporation of the fuel. Emissions due to the production and transport of fossil fuels are attributed to oil and gas wells, coal mines, gas processing plants, oil refineries, pipelines, oil and gas storage facilities, trucks and rail shipment of petroleum

products, gas distribution systems. Electric utilities, rather than electricity consumers, are responsible for the emissions associated with fossil-fired generation.[64]

Environment Canada reports greenhouse gas emissions due to fossil fuel use on farms in 1995:

Stationary fuel combustion	2,580	kt CO_2 equivalent
Transportation fuel combustion	9,010	kt CO_2 equivalent
Non-energy fuel use	110	kt CO_2 equivalent
Total	**11,700**	**kt CO_2 equivalent**

Almost the same result is obtained by estimating greenhouse gas emissions due to fossil fuel combustion on farms using energy consumption figures interpolated from the Farm Energy Use Survey. These figures are shown in Table A-1. Energy use for residential and business use, by fuel type, is interpolated from Farm Energy Use Survey data for 1980 and 1996. The result is estimated greenhouse gas emissions due to fossil fuel use on farms of 11,761 kt CO_2 equivalent for 1995 of which 75 percent is for business purposes and 25 percent is for residential uses.

Table A.1: Estimates of greenhouse gas emissions due to fossil fuel use on farms, 1995

	Emissions factor	Residential use		Business use		Total
Energy type	t CO_2 e/TJ	TJ	kt CO_2 e	TJ	kt CO_2 e	kt CO_2 e
Electricity		10,200		19,900		
Natural gas	49.695	18,800	934	25,800	1,282	2,216
Light fuel oil	73.170	7,400	541	1,600	117	658
Gasoline	69.324	11,000	763	32,900	2,281	3,044
Diesel	70.764	8,700	616	70,100	4,961	5,577
Liquid petroleum gases	60.635	2,200	133	2,200	133	266
Total		**58,300**	**2,987**	**152,500**	**8,774**	**11,761**

Sources: Energy consumption for residential and farm use in 1995 interpolated from Farm Energy Use Survey data for 1980 and 1996 provided by Maurice Korol, Agriculture and Agri-Food Canada. Physical units converted to TJ using coefficients from National Energy Board 1994. Emission coefficients from National Energy Board 1994, Appendix 11. Emission coefficients are CO_2 and CH_4 emissions expressed as CO_2 equivalent based on the mid-point values of the ranges provided.

Environment Canada reports that energy-related CO_2 emissions on farms were almost constant from 1990 through 1995, but increased in 1996.

64. It is possible to design policies to limit greenhouse gas emissions that place responsibility for the life-cycle emissions on the energy consumer. Such a policy would require complex accounting to track the upstream emissions associated with particular energy supplies. It is analogous to calculating total energy use by Canadian agriculture. Weseen, Lindenbach and Lefebvre 1999 estimate that a little over 40 percent of the total energy input takes the form of electricity and fossil fuel use on farms. Most of the energy input, almost 60 percent, takes the form of fertilizers, pesticides, machinery and buildings, which are produced elsewhere. Under a life-cycle system, farmers would be responsible for the emissions associated with the off-site production of those inputs. See Hornung and Haites 1998 for a discussion of the issues involved in designing an emissions trading system that holds participants responsible for life-cycle emissions.

The main options for reducing energy-related greenhouse gas emissions are to improve energy efficiency or to switch to less carbon-intensive fuels. Energy efficiency options include use of more fuel-efficient vehicles and better insulation of heated buildings. Fuel switching options include use of natural gas or propane instead of petroleum products or use of biogas recovered from manure handling systems.

A.2 Enteric Fermentation[65]

Both ruminant (cattle, horses, sheep) and non-ruminant (swine, poultry) agricultural livestock generate methane (CH_4) emissions. Most of the CH_4 is generated by ruminant animals, in which microbial metabolism of nutrients is the major source of the gas. Environment Canada reports CH_4 emissions due to enteric fermentation in 1995:

Cattle	17,000	kt CO_2 equivalent[66]
Pigs	380	kt CO_2 equivalent
Other	260	kt CO_2 equivalent
Total	**18,000**	**kt CO_2 equivalent**

Table A-2 provides a more detailed estimate of the CH_4 emissions due to enteric fermentation. The figures in Table A-2 are similar to those given above, which are the most recent and authoritative estimates, except that the emissions for cattle are about 15 percent too low.

Table A.2: Domestic livestock population and related enteric fermentation, greenhouse gas emissions, 1995

	Population 1995 (million)	CH_4 emissions (kt CH_4)	CO_2 emissions (kt CO_2-Eq)
Beef cattle	12.4	563	11,800
Dairy cattle	1.3	133	2,800
Swine	11.9	19	400
Sheep, goats	0.7	5	100
Horses, mules	0.4	5	100
Poultry (all types)	116.1	neg.	neg.
Total		**725**	**15,200**

Source: Jacques, Neitzert and Boileau 1997.

Beef cattle are responsible for most of the CH_4 emissions attributed to enteric fermentation beacuse of the size of the herd and the high emission rate per head versus other livestock. There were approximately 12.4 million beef cattle in Canada in 1995, with 3–4 million on feedlots or newborns. The remainder were range feeding, which makes management of the emissions more difficult and expensive.

65. This section is drawn from CHEMinfo Services Inc. 1998.

66. CO_2 equivalent emissions are calculated using the 100-year GWP values for different greenhouse gases. The climate change impacts of greenhouse gases are measured relative to the impact of CO_2 so the GWP of CO_2 is 1.0 by definition. The GWPs of CH_4 and N_2O are 21 and 310 respectively.

Environment Canada reports that emissions due to enteric fermentation increased about 20 percent between 1990 and 1996, almost entirely due to increased emissions from cattle.

Many factors influence annual CH_4 emissions from enteric fermentation, including temperature, diet, animal population, animal size, feed additives and livestock management practices. Emissions are affected by the efficiency with which the animal utilizes feed. This efficienty depends on many factors, so there is substantial variance in emissions across animals of a given type and among different types of animals.

Technologies that can reduce CH_4 emissions by livestock include greater use of feed additives (ionophores, antibiotics), steroid implants, improved livestock management and feeding practices, and bioengineering. Selected technologies and the estimated reduction in CH_4 emissions per head are listed in Table A-3. All of these technologies and practices increase the production of milk or meat in relation to the amount of feed utilized or time taken and so reduce CH_4 emissions.

Table A.3: Technologies to reduce methane emissions from cattle

	Reduction per head
Dairy cattle	
Management practices that improve productivity	10–15%
Use of bST hormone to increase production	3–7%
Beef cattle	
Management practices that improve productivity (improve cow-calf sector reproductive performance)	20–35%
Improve efficiency using ionophores	5–15%
Steroid implants on range cattle	< 5%

Source: CHEMinfo Services Inc. 1998.

Animal nutrition programs can be used to some degree by owners of all animals to increase productivity and so reduce CH_4 emissions. In cow-calf operations for example, (since beef cattle account for such a large share of total enteric emissions) poor nutrition contributes to low pregnancy rates (therefore low weaning percentages), and difficulty in getting cows to calve at 24 months. In forage-based production programs (as in many Western Canadian operations), producers can improve nutritional management in three ways:

- soil testing to determine fertilizer requirements for their forage
- assessing forage quality to determine supplementary nutrients required
- eliminating toxic plants that can influence animal productivity.

It is estimated that these and other management techniques (such as artificial insemination to ensure high pregnancy rates, veterinary care and vaccinations) can increase productivity 20-35 percent, and achieve similar reductions in greenhouse gas emissions.

A.3 Livestock Manure[67]

Livestock manure gives rise to both methane (CH_4) and nitrous oxide (N_2O) emissions of approximately equal magnitude when expressed on a CO_2 equivalent basis; 4,300 kt CO_2 equivalent of CH_4 and 4,500 kt CO_2 equivalent of N_2O in 1995.

Environment Canada disaggregates the CH_4 emissions, but not the N_2O emissions, by type of livestock and provides the estimates for 1995:

	Methane		Nitrous oxide	
Cattle	1,600	kt CO_2 equivalent		
Pigs	2,500	kt CO_2 equivalent		
Poultry	190	kt CO_2 equivalent		
Other	3	kt CO_2 equivalent		
Total	**4,300**	**kt CO_2 equivalent**	**4,500**	**kt CO_2 equivalent**

Environment Canada reports that greenhouse gas emissions from livestock manure increased about 13 percent between 1990 and 1996. CH_4 emissions increased about 10 percent while N_2O emissions increased 18 percent over the period. Almost all of the increase in CH_4 emissions came from pig manure.

Livestock waste decomposition occurs either aerobically or anaerobically. Under aerobic conditions, organic material in the waste is decomposed into CO_2 and stabilized organic material. Nitrogen compounds in the manure are converted to nitrates producing a small quantity of N_2O in the process. Under anaerobic conditions, organic material in the waste is decomposed into CH_4, CO_2, and stabilized organic material. Nitrates are converted to nitrogen gas and small quantities of N_2O.

Manure management systems that utilize anaerobic conditions (liquid/slurry storage systems, pit storage systems, and anaerobic lagoons) contribute most of the CH_4 and N_2O emissions. Only a small percentage of livestock manure is managed with these systems, but that small percentage is estimated to be responsible for about 60 percent of global livestock manure CH_4 emissions.[68]

Hog operations are more likely to use manure management systems that promote anaerobic decomposition so pigs are responsible for almost 60 percent of the manure related CH_4 emissions. Due to the large population, beef cattle represent approximately 75 percent of the manure related CH_4 emissions for cattle. Beef cattle are more likely to be range animals, promoting aerobic decomposition of manure. Dairy cattle contribute 25 percent of the manure related CH_4 emissions for cattle, despite the relatively small population, because they are herded into barns frequently and the manure is often stored in pits or lagoons, promoting anaerobic decomposition.

67. This section is drawn from CHEMinfo Services Inc. 1998.

68. See U.S. Environmental Protection Agency (EPA) 1992, pp. 11-15.

The two main technological options for reducing CH_4 emissions from livestock manure are aerobic composting and anaerobic digesters:

- Several types of aerobic composting technologies are currently being developed in Canada. These systems use various processes to compost aerobically liquid livestock manure to produce fertilizer which can be applied to fields or sold on the commercial or consumer markets. Few, if any, commercial farms (apart from pilot project participants) in Canada have installed aerobic composting systems. However, several Canadian companies are close to full-scale commercialization of their aerobic composting systems for manure.
- Most of the research on reducing CH_4 emissions from livestock manure has focused on anaerobic digesters to collect the biogas produced through decomposition of the manure. Collected biogas (CH_4) can be used as a fuel to generate electricity or for heating or cooling needs.[69] Anaerobic digester designs include covered lagoons, plug flow, and complete mix digesters. These digesters, suitable for large-scale, intensive farm operations, can reduce CH_4 emissions up to 70–80 percent.

Options that reduce CH_4 emissions from manure will generally reduce N_2O emissions as well. The most appropriate technology for a particular farm will depend upon the volume of manure, climatic conditions, options for using biogas, and other factors.

A.4 Fertilizer Use[70]

In 1995 synthetic fertilizer application accounted for a total of 4,000 kt of CO_2 equivalent N_2O emissions (13 kt of N_2O). Emissions from synthetic fertilizer application increased almost 60 percent between 1990 and 1996 due to more intensive fertilizer application, especially nitrogen-based fertilizers. As seen in Table A-4, anhydrous ammonia accounts for about 85 percent of the N_2O emissions due to fertilizer use in Canada. It has a much higher emissions factor than any other type of fertilizer due mainly to the fact that it is applied as a liquid.

When nitrogen fertilizers are applied to soil, N_2O emissions increase unless the amount of nutrient applied precisely matches the plant uptake and soil capture. N_2O emissions from fertilizer application occur due to anaerobic and aerobic processes. Most of the nitrogen is oxidized to nitrates before it is taken up by the plants. This process is referred to as nitrification.

In an anaerobic environment, such as waterlogged soil, nitrates are reduced by facultative anaerobic bacteria to N_2O and nitrogen gas, which are emitted to the atmosphere. This process is referred to as denitrification; the loss of nitrogen in the soil.[71] Several factors control the rate of the two microbial processes (nitrification and denitrification) that result in N_2O emissions. Among these variables are soil water content, temperature, nitrate or ammonium concentrations, available organic carbon for dentification, and pH.[72]

69. Ibid.
70. This section is drawn from CHEMinfo Services Inc. 1998.
71. Jacques, Neitzert and Boileau 1997.
72. Intergovernmental Panel on Climate Change (IPCC) 1996, p. 761.

Table A.4: Canadian fertilizer use and related N_2O emissions, 1995

Fertilizer material	Quantity (tonnes)	N content (tonnes)	Average loss (% N)	N_2O (tonnes)
Nitrogen (N)				
Urea	1,304,730	600,176	0.11	1,037
Ammonia sulphate	205,330	43,119	0.12	81
Ammonium nitrate	256,697	87,957	0.26	369
Anhydrous ammonia	553,727	442,581	1.63	11,336
Nitrogen solutions	232,906	66,029	0.11	114
Other nitrogen	3,199	0	0.11	0
Calcium ammonium nitrate	32,849	8,470	0.03	4
Phosphate				
Monoammonium phosphate	937,031	103,073	0.12	194
Diammonium phosphate	180,785	32,541	0.12	61
10-34-0	1,705	238	0.11	0
Other fertilizers	293,804	64,171	0.11	111
Total	**4,002,765**	**1,448,355**		**13,300**

Source: Jacques, Neitzert and Boileau 1997.

Management practices and technologies that can reduce N_2O emissions from fertilizer use include three processes: fertilizer management practices, nitrification inhibitors and irrigation water management.

Fertilizer management practices match mineral fertilizer to crop requirements better and so reduce the demand for fertilizer and the consequent N_2O emissions. This increased efficiency can be achieved in seven ways:[73]

- using nitrogen testing kits to match more closely nutrient inputs to crop requirements
- regularly calibrating machinery to ensure accurate delivery of fertilizers
- paying careful attention to the frequency, timing and appropriate placement of fertilizer applications
- adjusting the rate of nitrogen to a reasonable yield goal for the specific crop and field
- placing nitrogen deep enough in the soil to lower the N_2O/nitrogen gas ratio when denitrification does occur
- taking into account soil nitrogen mineralization and the nitrogen from legumes, manures, organic wastes, irrigation water and other potential sources
- dispensing with the maintenance concept, which fails to recognize the amount of residual nitrogen in the soil and the soil's nitrification potential.

73. See Organization for Economic Cooperation (OECD) 1996, p. 26 and Center for Agricultural Science and Technology 1992, p. 76.

Nitrification inhibitors are chemicals applied with fertilizers to maintain the added nitrogen as ammonium (NH_3). Nitrification inhibitors stabilize fertilizer applied as NH_3 or in the NH_4+ form by inhibiting activity of the *Nitrosomonas* bacteria in the first step of the nitrification process. Nitrogen losses are reduced if applied nitrogen remains in the NH_4+ form for several weeks after application, especially when applied in the fall or when there may be a heavy rainfall during the spring. An inhibitor, such as nitrapyrin or acetylene, can be effective in many field crop situations.[74]

Irrigation water management can reduce the number of denitrification cycles. Emissions of denitrification gases usually occur immediately following each irrigation. Managing the application of irrigation water can reduce the number of denitrification cycles and also help to move soluble nitrogen deeper into the soil where supplies of oxygen are more limited, thus reducing N_2O formation.

A.5 Soils[75]

Soils are a source of CO_2 and N_2O emissions. Environment Canada estimates the various categories of emissions from agricultural soils in 1995:

CO_2 emissions by soils	3,000	kt CO_2 equivalent
Direct N_2O emissions by soils[76]		
Manure as fertilizer	3,000	kt CO_2 equivalent
Biological nitrogen fixation	4,000	kt CO_2 equivalent
Crop residue decomposition	8,000	kt CO_2 equivalent
Cultivated organic histosols	50	kt CO_2 equivalent
Grazing animals	3,000	kt CO_2 equivalent
Indirect N_2O emissions by soils	10,000	kt CO_2 equivalent
Total	**31,050**	**kt CO_2 equivalent**

CO_2 emissions from agricultural soils declined significantly between 1990 and 1996, but this decline has been partially offset by increased N_2O emissions, so that total emissions from soils declined about five percent from 1990 to 1996.

The trend in CO_2 emissions is toward a state of equilibrium of carbon in Canadian soils, and was predicted to occur in 1997. The CENTURY model estimated that the rate of decline in CO_2 emissions from 1990–1996 was approximately five times greater than for 1980–1990, reflecting changes in agricultural practices.[77]

Emissions of CO_2 from agricultural soils can be reduced through greater use of perennial forage crops, application of manure,[78] reduced tillage and reduced use of summer fallow. Summer fallow is used extensively in semi-arid areas of Canada to offset rainfall variability

74. Center for Agricultural Science and Technology 1992, p. 77.

75. This section is drawn from CHEMinfo Services Inc. 1998.

76. Environment Canada includes N_2O emissions from the use of synthetic fertilizers, discussed in the previous section, in the direct soil emissions. They are excluded here to avoid double counting.

77. Jacques, Neitzert and Boileau 1997, p. 52.

78. Excessive application of manure can lead to N_2O emissions, which could more than offset the CO_2 sequestration benefits. The conditions under which manure is applied and the quantity applied need to be assessed to avoid generating N_2O emissions.

and increase soil moisture storage. Eliminating or reducing summer fallow through better water management could significantly increase carbon in semi-arid croplands and decrease soil erosion.

Greater use of perennial forage crops can also significantly increase soil carbon levels, due to high root carbon production, lack of tillage disturbance, and protection from erosion. Where climate permits, winter cover crops decrease erosion and provide additional inputs of carbon, thereby increasing soil organic carbon. Another management practice to sequester more carbon is to apply large quantities of manure to the fields. Reduced or no-tillage often (but not always) increases soil carbon. Several studies have shown however, genuine increases in soil organic content as a result of reduced tillage.

A.6 Fossil Fuel Use in the Transport of Food Products

The transport of food products includes the shipment of crops, livestock and other products from farms to processing plants or rail shipment points, rail shipment of crops, products and livestock to processing plants or to the border for export, shipment of food products from processing plants to storage or distribution centres by rail or truck, and shipment of food products from processing plants and distribution centres to restaurants and stores.

Data on fuel consumption for food transport are not available, so the greenhouse gas emissions attributed to this activity cannot be calculated.

Emissions per litre of diesel fuel are essentially the same whether the fuel is used for rail or truck transport. Total greenhouse gas emissions per litre of fuel are about equal for motor gasoline and diesel fuel. Thus, the emissions depend on the fuel used per tonne-km of product shipped. In general, railways use less fuel than diesel trucks, and diesel trucks use less fuel than gasoline trucks per tonne-km of product shipped.

Selecting the most fuel efficient transport option reduces greenhouse gas emissions. But fuel use per tonne-km depends significantly on variables such as the load factor and the availability of freight for the backhaul, so the choice will vary with the circumstances. Selection of the transport option will, of course, also consider other factors such as speed, reliability and cost.

A.7 Fossil Fuel Use in Food Processing

Fossil fuel use by food and beverage industries gives rise to CO_2, and much smaller quantities of CH_4 and N_2O . Data on energy use by type in the food and beverage industries, as defined by the Standard Industrial Classification, are collected by Statistics Canada through different surveys. Estimates of the greenhouse gas emissions by the food and beverage industries in 1995 are presented in Table A-5.

Fossil fuel use by the food and beverage industries released about 3,744 kt of CO_2 equivalent emissions. These industries were responsible for about 3.8 percent of Canada's industrial energy use in 1995 and for about 4.8 percent of the industrial greenhouse gas emissions.

Table A.5: Estimates of greenhouse gas emissions by the food and beverage industries, 1995

	Emissions factor	Residential use		Business use		Total
Energy type	**t CO_2 e/TJ**	**TJ**	**kt CO_2 e**	**TJ**	**kt CO_2 e**	**kt CO_2 e**
Electricity		23,025		2,446		
Natural gas	49.695	56,491	2,807	8,696	432	3,239
Middle distillate	73.170	1,846	135	292	21	156
Heavy fuel oil	74.038	4,373	324	325	24	348
Liquid petroleum gases	60.635	X		15	1	1
Steam		1,978		0		
Total		**87,764***	**3,266**	**11,777***	**478**	**3,744**

Notes: *Total differs from sum of the figures for individual energy types. X Data are confidential.

Sources: Nyboer and Bailie 1997 for energy consumption data. Emission coefficients from National Energy Board 1994, Appendix 11. Emission coefficients are CO_2 and CH_4 emissions expressed as CO_2 equivalent based on the mid-point values of the ranges provided.

Total energy use in the food and beverage industries increased slightly from 1990 through 1996, with rising energy use in the food industries being almost fully offset by declines in the energy consumption by the beverage industries. Energy use per unit of output (energy-efficiency) declined (improved) in both the food and beverage industries over this period.

Opportunities to reduce emissions due to fossil fuel use arise primarily through enhancing energy efficiency and fuel switching. Like most industries, the food and beverage industries have for many years improved their energy efficiency. Continuation and enhancement of these initiatives will help reduce greenhouse gas emissions. The opportunities for switching to less carbon-intensive energy sources may be limited. Fossil fuel use in these industries is dominated by natural gas, which is the least carbon-intensive fossil fuel. The main option then is to switch from fossil fuels to electricity, which shifts responsibility for the associated emissions to the electricity generators.[79] Depending upon the region of the country and the relative efficiency of the gas and electric technologies, such a shift could increase or reduce the emissions.

A.8 HFC Leakage from Refrigeration Systems[80]

Refrigeration is important for the food and beverage industries. Traditionally, the circulating fluids in refrigeration systems have been CFCs.[81] CFCs destroy the stratospheric ozone layer

79. Although policies to limit greenhouse gas emissions may hold the utility responsible for the emissions associated with electricity generation, the costs of compliance will be reflected in the price of electricity. Thus firms should consider the net impact on overall greenhouse gas emissions before switching from a natural gas to an electric technology.

80. This section is drawn from CHEMinfo Services Inc., 1998.

81. CFCs, HCFCs and HFCs have a number of other applications including manufacture of foams and cleaning of circuit boards. Use of CFCs in all of these applications has been, or is being, phased out. Use of HCFCs in all of these uses will also be phased out. HFCs are not regulated by the Montreal Protocol since they do not destroy the stratospheric ozone layer.

and are controlled by the Montreal Protocol. Production of CFCs for use in developed countries was phased out at the end of 1996. The replacement products include HCFCs and HFCs.[82] HCFCs also destroy the stratospheric ozone layer and are being phased out under the Montreal Protocol. Use of HFCs and their release into the atmosphere is expected to grow rapidly as the use of CFCs and HCFCs is phased out.

The dominant use of HFCs at present is in vehicle air conditioning, where HFC-134a is used to replace CFC-12. Refrigeration is the second largest use of HFCs. The HFCs used as working fluids for different types of refrigeration systems include HFC-125, HFC-134a and HFC-143a. Refrigeration use accounted for just over 20 percent of total HFC consumption in Canada during 1995. Because of its use in vehicle air conditioners and other applications, HFC-134a accounted for almost 90 percent of the HFCs used in Canada during 1995.[83]

Canada's Greenhouse Gas Emissions Inventory reports no HFC emissions from 1990 through 1994.[84] Total HFC emissions in 1995 are estimated at 3 kt but because of the high global warming potentials of HFCs this corresponds to 500 kt of CO_2 equivalent emissions.[85] HFC consumption and its related emissions are likely to increase rapidly over the next two decades and could reach 22 kt in 2020 if all CFC and HCFC applications are converted to HFCs.

Emissions are calculated from HFC consumption data. Since the HFCs used in air conditioners and refrigeration systems are working fluids circulating in closed systems, they are emitted only when the systems leak or are serviced. Emissions are estimated at four percent of the charge for new air conditioning systems, 100 percent of the charge used for servicing, and 10 percent of the refrigeration use. When emissions are expressed on a CO_2 equivalent basis, refrigeration accounts for about 20 percent of the HFC emissions.

Options for reducing HFC emissions include reducing leakage from air conditioners and refrigeration systems and switching to any of four alternative working fluids:

- lower GWP HFCs (these tend to be more flammable)
- propane/butane (flammable, but currently used in European domestic refrigeration)
- ammonia (toxic, but used in large commercial refrigerated warehouses and ice arenas)
- CO_2 (requires very high compression pressures).

The capture and recycling of working fluids to minimize leakage is mandated by regulation for all auto air conditioning and refrigeration service in Canada.

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82. CFCs and HCFCs (as well as HFCs) contribute to climate change. However, CFCs and HCFCs are not covered by commitments under the Kyoto Protocol because they are already being phased out under the provisions of the Montreal Protocol. Thus, the Kyoto Protocol commitments apply only to HFCs.

83. HFC-134a is not as efficient as HCFCs (particularly HCFC-22 and R-502 blends) in medium temperature refrigeration applications. HCFCs dominate these applications as well as the foam production and aerosol applications. But the use of HCFCs in these applications ultimately must be phased out.

84. Jacques, Neitzert and Boileau 1997, pp. xv and 48.

85. The 100-year GWP values for the principal HFCs are: HFC-125 = 2,800; HFC-134a = 1,300; and HFC-143a = 3,800.

A.9 Wastewater, Landfilling and Composting[86]

Food and beverage processing produces organic wastes that become part of liquid or solid waste streams. Three situations produce greenhouse gas emissions from organic wastes:

- When the organic material in wastewater decomposes in an anaerobic environment CH_4 is produced. N_2O can also be produced through microbal denitrification of the organic matter.
- When degradable organic waste decomposes in an anaerobic environment, landfill gas, which consists mainly of CH_4 and CO_2, is produced.[87] The quantity of landfill gas produced depends mainly on the composition of the waste, but is also affected by temperature, precipitation, acidity, availability of nutrients, and other factors.
- Anaerobic decomposition of food wastes from composting results in the formation of CH_4.[88] Centralized composting facilities usually operate under aerobic conditions to improve efficiency and reduce odours and so do not produce CH_4 emissions.

The quantities of organic waste generated by the food and beverage industries and the manner in which they were disposed are not available. Thus, it is not possible to calculate the greenhouse gas emissions due to disposal of these wastes by the industry. However, total emissions from landfills in 1995, net of CH_4 recovered, were estimated at 18,000 kt CO_2 equivalent and from wastewater treatment and composting at 411 kt CO_2 equivalent.

Under the principles used for the emissions inventory, food and beverage industries are responsible only for the wastes they treat themselves. Many food and beverage plants are required to undertake some treatment of their wastes, and/or to pay sewage treatment surcharges, and/or to pay waste disposal charges for their solid wastes. Those fees could increase if landfills and wastewater treatment plants are required to reduce their greenhouse gas emissions, thereby making on-site treatment more attractive.

Greenhouse gases from disposal of organic wastes from the food and beverage industries can be reduced by four practices:

- reduce the quantity of waste
- capture and use CH_4 produced by wastewater treatment facilities
- compost, preferably in aerobic conditions, rather than landfill solid wastes
- capture and use CH_4 from landfills.

86. This section is based on Jacques, Neitzert and Boileau 1997, pp. 61–66.

87. CO_2 emissions are not included in the inventory on the assumption that the biomass is sustainably produced. Thus, the emissions simply release CO_2 previously removed from the atmosphere.

88. Composting, even under anaerobic conditions, reduces CH_4 emissions almost 50 percent relative to landfill disposal of the same wastes according to Jacques, Neitzert and Boileau 1997, p. 66.

A.10 Summary

Greenhouse gas emissions by the agriculture and agri-food sector are summarized in Table A-6. Greenhouse gas emissions from the sector amount to at least 78,000 kt CO_2 equivalent, which was over 10 percent of Canada's total emissions during 1995.

Table A.6: Summary of greenhouse gas emission estimates for the agriculture and agri-food sector in Canada, 1995

	CO_2	CH_4	N_2O	HFCs	Total	
Emission source	**(kt)**	**(kt)**	**(kt)**	**(kt)**	**CO_2 e**	**%***
Fossil fuel use on farms						
Residential use	3,000				3,000	0.5
Business use	8,700				8,700	1.4
Enteric fermentation		840			18,000	2.9
Livestock manure		204	14		8,800	1.4
Synthetic fertilizer use			13		4,000	0.6
Soils	3,000		94		32,300	5.2
Fossil fuel use in transport of food products					?	?
Fossil fuel use in food processing	3,745	—			3,745	0.6
HFC leakage from refrigeration systems				0.07	100	—
Wastewater, landfilling and composting					?	
Total emissions(kt)	**18,500**	**1,050**	**121**	**0.07**		
(kt CO_2 e)	**18,500**	**22,000**	**38,000**	**100**	**78,600**	**12.7**
			Sequestration			
Soil sequestration	8,000 to 25,000				8,000 to 25,000	1.3 to 4.0

Note: *Percent of Canada's total greenhouse gas emissions of 619,000 kt CO_2 equivalent in 1995.

N_2O emissions from soils are the largest component of greenhouse gas emissions. When the emissions from synthetic fertilizer use and CO_2 emissions from soils are included, soils account for 5.8 percent of Canada's total greenhouse gas emissions. Livestock are the next largest source of greenhouse gas emissions. When CH_4 emissions due to enteric fermentation are combined with the CH_4 and N_2O emissions from livestock manure, they account for about 4.3 percent of Canada's total greenhouse gas emissions. Fossil fuel related CO_2 emissions represent less than 25 percent of total greenhouse gas emissions by the agriculture and agri-food sector.

Estimates of the potential for sequestration in agricultural soils, if this sequestration is allowed under the Kyoto Protocol, range from 8,000 to 25,000 kt CO_2 equivalent per year. This range is equivalent to 1.3–4.0 percent of current emissions. These figures suggest that sequestration in agricultural soils is capable of offsetting about 10–30 percent of the greenhouse gas emissions from the agriculture and agri-food sector.